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# SCIENCE

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## *In This Issue*

## The Neutron, the Intermediate or Compound Nucleus, and the Atomic Bomb

William Draper Harkins

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SCIENCE

Vol. 103, No. 2671 Friday, March 8, 1946

# The Neutron, the Intermediate or Compound Nucleus, and the Atomic Bomb[1]

William Draper Harkins

*The University of Chicago and the Universal Oil Products Company*

THE ATOMIC BOMB IS A MONSTER reared by war. A fact revealed by history is that the offense grows much more rapidly in power than the defense in its ability to cope with it. Indeed, this seems to be a natural law, since warfare was formerly restricted to the surface of the earth and was, therefore, two-dimensional. Now, it is rapidly rising above those limits of the atmosphere suitable to the life of man and is expanding in the third dimension. The offense can choose any portion of space thus made available, but it is impossible for the defense to cover every location in this space. Concomitant with this conquest of space is one of time, since jet propulsion makes it possible to exceed the velocity of sound.

Now, in addition to the conversion of space into the slave of war, nuclear energy is also enslaved. The danger here is one of mass and space. A few pounds of uranium 235 or of plutonium 239 carried in small packages may be put into such a form as to destroy a whole city, being set off by a time clock. The apparatus necessary to detonate the material would be much larger.

In the opinion of the writer, grave errors in connection with the bomb have imperiled the international situation. These need not be cited, but, the benefits to mankind of the energy made available are small compared to the uncertainty thereby introduced into human life. Man has not as yet attained the state of moral and intellectual development to make it safe to have such a weapon. Therefore, (1) no more bombs should be produced; (2) any uranium 235 or plutonium 239 now available should be distributed to universities or hospitals for scientific or medical work only; (3) a world association of scientists should be formed to oppose work on the bomb; (4) the United States should use its utmost influence to establish at once a temporary world organization, to be made permanent later, to suppress the use of the bomb.

Presumably this would require some type of World Government to control war. This might be associated with the United Nations Organization.

What has been written thus far refers to the bomb. However, nothing can stop progress in the use of the energy of fission for the development of power, but this should be under the control of the World Government to prevent its degeneration into the purposes of war. On account of the injurious effects of the radiations given off, the shielding essential to protect life necessitates large installations if human beings are near by. Thus, while ships might make direct use of this power, it is not suitable for automobiles.

While no mention of thorium is made in the paper which follows, it seems not unlikely that this element will be utilized more than any other. If this is done, it is probable that one method will be to convert this into uranium. To thorium of mass 232 a neutron would be added, thus forming thorium 233, which would then change into element 91 by loss of an electron and into element 92 (uranium) by the loss of another electron. Presumably, this isotope of uranium of mass 233 would undergo fission. Since thorium is more abundant than uranium 238, there is no lack of an abundant supply. If this comes true, uranium 233 and plutonium 239 would become the sources of industrial energy. Uranium 235 is less

[1] This article had its origin in an attempt to answer many questions which arose after the first use of the atomic bomb and the publication of the Official Report written by H. D. Smyth. The only direct connection of the writer with this work was the building of the Chicago cyclotron, which was used in the Metallurgical Project at the university. An attempt has been made, without too much success, to avoid as much as possible topics discussed in the Official Report. Obviously, however, many of the topics considered there must be discussed here, if what is presented is made at all intelligible. For fifteen years, from 1913 to 1928, the writer and his collaborators were the only ones in America engaged in work on the structure of the nucleus of the atom. This involved the earliest use of the Wilson Cloud Chamber for the photography of what is commonly called nuclear disintegration. This work gave rise to an idea which may be expressed as follows: In what had been earlier considered as a direct disintegration of the atom the actual primary process is not the disintegration but the synthesis of an activated nucleus which disintegrates later, although after an extremely short life. It is the relations of this idea which are discussed in this article.

suitable on account of the necessity of at least partially separating it from uranium 238.

## I. Introduction: Disintegrative Synthesis of Atomic Nuclei

There are certain relations discovered long ago and discussed here which are involved in the action of what has been designated as the atomic bomb, or, more properly, the nuclear bomb. Some of these may make it more simple to understand what occurs in the release of the extremely great amount of energy, as compared with the mass involved, when the bomb explodes.

The nucleus of the atom is an extremely minute body which may consist of only one particle, or of as many as 239 particles, very tightly bound together by nuclear forces. These primary particles are designated as the proton (nucleus of the hydrogen atom), with a mass of 1.00758 and unit positive charge of electricity, and the neutron, of mass 1.00893 without an electrical charge. The diameter of a single proton or neutron in any nucleus is about $3 \times 10^{-13}$ cm.

Developments based upon the discovery of radioactivity by Becquerel in 1896 and the later discovery and separation of radium by Mme. Curie showed that the heaviest or radioactive atoms may disintegrate naturally to give off either negative electrons, which may even approach the velocity of light, or alpha particles, proved by Rutherford and Royds in 1909 to give gaseous helium when they are collected. Later it was shown that an alpha particle, which has a positive charge of 2, due to the two protons which it contains, is actually the nucleus of the helium atom. Each alpha particle contains two protons which would repel each other if they were not bound together by two neutrons. These alpha particles may have velocities as high as, or even higher than, 12,000 miles per second.

In 1919 Rutherford in a very remarkable and extremely simple experiment showed that he was able to obtain the disintegration of one of the lightest atoms, which he assumed to be that of nitrogen. This led to the idea that atomic nuclei may be disintegrated artificially, since the nuclei of the nitrogen atom which he used seemed to be split into two particles, one a carbon nucleus and the other a proton, by a mere, though excessively energetic, blow of a fast alpha particle.

Soon after this the writer came to the conclusion that the simplest method which could be used to determine whether or not a nucleus of the nitrogen atom is split in this way would be to use the Cloud Chamber of C. T. R. Wilson, a most remarkable apparatus which makes it possible to photograph the tracks of atoms as described later. From photographs obtained in this way the writer came to the conclusion that the primary action is not a disintegration but a synthesis of new nucleus, in the formation of which the nucleus used as a projectile is always captured by that used as a target (Fig. 1). The compound nucleus thus formed disintegrates later after an *extremely* short life. Nevertheless, the life

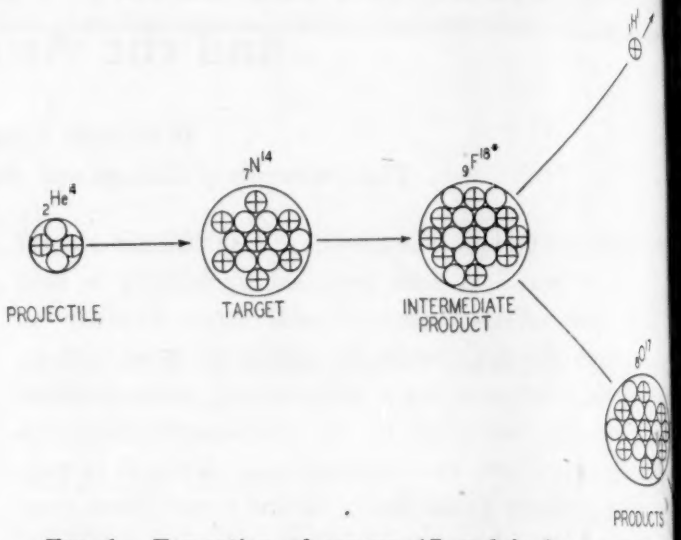


Fig. 1. Formation of oxygen 17 and hydrogen 1 by the disintegration of fluorine 18, the intermediate nucleus formed by the impact of helium 4 with nitrogen 14. Open circles = neutrons. Circles with plus signs = protons. At higher energies the excited fluorine nucleus disintegrates in two ways (1) that given in the diagram, and (2) to give a neutron and positive electron in place of a proton (= hydrogen 1).

period is sufficient to make the disintegration of this nucleus, which is always in an excited state, an event entirely independent of its synthesis, since enough time elapses to distribute the energy introduced with the projectile through the whole nuclear system. Thus, the disintegration of this nucleus does not depend upon what nuclei have joined together to form it, *but only upon the state in which the excited nucleus exists.*

This greatly simplifies the consideration of nuclear transformations, since, as illustrated later, the same composition of the compound nucleus and essentially the same activated state may be obtained by the use of different projectiles. For example, carbon 12 ($C^{12}$) can be formed by the impact of hydrogen 1 ($H^1$) upon boron 11 ($B^{11}$), or of hydrogen 2 ($H^2$) upon boron 10 ($B^{10}$), but the excited carbon nucleus thus formed gives, in either case, as the final result of its disintegration, three alpha particles, *i.e.* three helium atoms. Thus, it is not the disintegration which is artificial, since this is entirely spontaneous, but it is the synthesis of the compound nucleus which may be brought about by artificial means.

While the writer's theory of the occurrence of nuclear reactions by the formation of an intermediate excited nucleus was accepted by a very few experi-

mental physicists, it met with very strong opposition on the part of nuclear theorists during the years 1926–36, the period in which experimental evidence in favor of these ideas was being collected. This opposition was due to the fact that, whereas the nucleus consists of an aggregation of protons and neutrons bound together by an extremely strong interaction, giving a density so great that it is incomprehensible to ordinary human beings, theoretical physicists of the period treated it upon the basis of the Hartree formula, which in itself assumes a loosely bound aggregation (the free particle model of the nucleus). For example, Bethe (*1*), who favored the idea that the interaction between the particles in a nucleus is small, in a private conference in June 1936, stated that the existence of the intermediate nucleus, as demanded by the theory of the writer, is impossible. Reviews by other theoretical physicists in 1934 stated that the law of conservation of energy would have to fall before such an intermediate nucleus could exist. These ideas were based upon the fact that at that time nuclear physicists assumed the existence of a very much smaller number of nuclear energy levels than were considered by the writer to be present.

Evidence in favor of the theory of the writer is considered in more detail later, but here it may be mentioned that the reactions which occur in the atomic bomb proceed according to the theory. Thus, either uranium 235 or plutonium 239 is an entirely innocuous material, since the atoms of these substances are quite stable, having the type of stability found in radioactive atoms of moderately long life. It is not these which disintegrate by fission to give the excessively high energy of the bomb, but in each case it is the intermediate, or compound, nucleus uranium 236 or plutonium 240, which disintegrates by fission to give the energy. These relations are considered in more detail in a later section.

## II. Energy of the Bomb

The effectiveness of the bomb is due to the fact that it develops an amount of energy which is enormous in comparison with the mass involved, in an exceedingly short space of time (of the order of a millionth of a second). This development of energy is accomplished by bringing about a nuclear reaction. A chemical reaction, such as the burning of coal or the explosion of an unstable compound, known as an explosive, may develop a large amount of energy. In general, a nuclear reaction which involves the same amount of mass develops from one to ten million times as much.

In 1897 Kaufman found that particles (in his experiments, negative electrons) have a higher mass when their velocity is high than when they are at rest. Eight years later Einstein developed a remarkably simple equation which the writer likes to consider from the following point of view. We may write an equation in which E represents energy in any form and m, mass in any form, as follows:

$$E = m$$

This equation may be said to be valid if both E and m are given in ergs, or both in grams, but in the use of this equation E cannot be expressed in ergs and m in grams. However, this can be done if the equation is written:

$$E = mc^2$$

which is Einstein's equation. The remarkable achievement of Einstein was that he showed that the transformation in units and dimensions involves a natural constant,

$$c^2 = (3 \times 10^{10})^2$$

which is the square of the velocity of light.

Others may prefer to write the equation as

$$-\Delta m \cdot c^2 = \Delta E.$$

This indicates that a decrease of mass of $\Delta$ m grams involves an increase in energy of $\Delta$ E ergs. That the energy developed in a nuclear reaction may be excessively large was shown in 1915 by Harkins and Wilson (*4*), who had been engaged in a consideration of the heat of the sun and stars. They found by the use of Einstein's equation that if 4 hydrogen atoms are by any series of processes converted into one atom of helium the energy liberated between the initial and final states is extremely large. Thus, a single pound of hydrogen by this "nuclear combustion" gives as much heat as the burning of *ten thousand tons,* or ten million pounds of coal. Here, the nuclear reaction gives ten million times the energy of the chemical reaction. Although later certain noted physicists considered that the reaction in which helium is formed occurs almost instantaneously, it was obvious that four exceedingly small protons could not meet and, in addition, lose two positive charges (the proton has a positive charge of one, and the helium nucleus or $\alpha$-particle a positive charge of two) in a sufficiently minute time to give such a synthesis. Thus, the reaction must of necessity occur in steps, but a consideration of these steps is not involved in the calculation of the energy.

The mass of the hydrogen atom nucleus (proton) is 1.00758 and of the helium atom 4.0039. The mass of the helium nucleus is $4.0039 - 2 \times (0.000549$ mass of electron$) = 4.0028$. Now, four protons have a mass of $4 \times 1.00758 = 4.0303$, so $4.0303 - 4.0028 = 0.0275$ is the loss of mass. Consider these masses in grams; then the decrease of mass is $-0.0275$ g and $E = 0.0275 \times 9 \times 10^{20} = 2.475 \times 10^{19}$ ergs for the formation of 4.0039 g of helium from 4.0325 g of hydrogen (these

masses now include the masses of the electrons outside the nucleus). This is $6.138 \times 10^{18}$ ergs per gram = $1.467 \times 10^{11}$ calories per gram = $6.654 \times 10^{13}$ calories per pound, or 25.6 million electron volts.

The calculation of the energy developed in the fission of uranium 236 or of plutonium 240 would be just as simple as that for the energy of synthesis of helium given above, if the masses of all the final products of the fission were known. The problem is discussed later, but the energy given by one pound of the uranium isotope is equivalent to that produced in the burning of (about) 1,300 tons of coal (about 200 million electron volts). Thus, the *disintegration* of this heavy nucleus gives less than one-sixth as much energy per unit mass as the synthesis of helium.

In 1893 and later, Landolt, in a classical experiment which involved a long series of very accurate weighings, endeavored to determine the loss of mass in a chemical reaction which evolves heat. In connection with the calculations of nuclear energy changes, Harkins and Wilson found, by the use of Einstein's equation, that in the formation of 18 grams of water from hydrogen and oxygen the energy evolved is equivalent to only 3 *billionths of a gram,* which explains Landolt's failure to detect the loss of mass.

## III. Electric Charge, the Principle of Electrical Neutrality and Atoms

One of the most fundamental laws of nature is that the electric charge of any "primary" particle may have a positive or negative sign, but the magnitude of the unit electric charge is invariable, *i.e.* the same (1.60 coulombs) for any single particle.

Furthermore, in any material body that we know, the number of negative charges is extremely closely equal to the number of positive charges. The departure of the earth as a whole from this principle of electrical neutrality is excessively small. Only extremely small bodies exhibit any considerable percentage variation from this principle. By definition any *atom* is electrically neutral: if it contains more negative than positive charges, it is designated as a negative ion, or with more positive than negative, a positive ion.

The nucleus of the atom, when it is free, as it may be at exceptionally high velocities, exhibits the greatest departure from electrical neutrality, since, according to our present philosophy, every charged particle which it contains is positive, *i.e.* a proton. A nucleus which is relatively "stable" may contain from one proton (hydrogen atom) to 92 protons (uranium atom) or even 94, since plutonium is moderately stable. The electrically neutral atom must then contain as many negatively charged particles (electrons) as the *number* of protons in the nucleus. This number (Z) is designated as the *atomic number,* though actually it is the *element number* in the periodic table of Mendelejeff.

The electron, or electrons, may be considered to move around the nucleus, where they form a cloud which is excessively tenuous, when considered in comparison with the high density of the nucleus. The mass of the proton is $1.672 \times 10^{-24}$ grams. If this is contained in the $1.4 \times 10^{-38}$ cc. considered as its volume, the density is $1.2 \times 10^{14}$ grams or 130 million tons per cc. Thus, the whole earth would have a diameter of only 460 meters, or less than a third of a mile (0.286 miles) if its *whole mass* were present as protons and neutrons packed as they are in the nucleus of an atom. The presence of electrons, however, reduces the density from $1.2 \times 10^{14}$ g per cc. to that of the earth (5.522 g per cc.) which is 2 million million times smaller.[2]

## IV. Elements and Isotopes

According to Section III, the number of electrons in an atom is equal to the number of protons in its nucleus. It was shown by Mendelejeff in 1868 that the chemical properties of the elements may be expressed as a periodic function of the atomic weight. In 1896, Rydberg and, later, van der Broek and, by direct experimental evidence, Moseley indicated that the relationship becomes more exact if the atomic number is considered instead of the atomic weight. According to more recent theory, the atomic number gives the positive charge on the nucleus which is equal to the number of protons which it contains.

The atomic numbers of the elements thus far found in nature vary from 1 to 94 so it is often said that there are 94 elements. Of these, however, the nuclei with 61, 85, and 87 protons have not as yet been discovered in any known material. However, they have been produced by artificial means. It should be considered that there is also another element of zero atomic number which consists of neutrons. These carry no charge and thus its atoms contain no electrons and have no ordinary chemical properties. Elements 93 and 94, neptunium and plutonium, have now been produced artificially, and obviously it is possible with sufficient amounts of plutonium to push the artificially produced elements to still higher atomic numbers. When the chemistry and the spectrum of any of these becomes well determined, it is possible that some of them may be found to exist in nature.

Until the year 1907 it was considered that each known element is actually elementary, but in this year

[2] The size of the nucleus is obtained by calculations made on the basis of the scattering produced in elastic collisions between nuclei and exhibits some variation with the velocities of the particles at the time of the collision.

Coy and Ross, of the Department of Chemistry of University of Chicago, made the remarkable discovery that there exist in thorium at least two varieties of this element. These have highly different stabilities, but the same chemical properties, and are now known as isotopes (*5*). The announcement of this discovery was made in the following simple statement: "In fact, it now appears doubtful whether it is possible by chemical treatment to separate any radiothorium from thorium." Both of these atomic species have the atomic number 90 and therefore belong to the same chemical element, although the atomic weights are 232 for thorium and 228 for radiothorium. It is now known that the element thorium consists of 6 isotopes. The known elements consist of from 1 to 10 isotopes, and the formation of these gives the existence of about 300 types of atoms (atomic species) in addition to the radioactive species of high atomic mass.

## V. Separation of Isotopes

The separation of the isotopes of uranium of atomic masses 235 and 238 has been one of the most important problems in the production of the atom bomb. For some time after the discovery of isotopes it was considered that isotopes were inseparable. However, in 1919, Harkins and Broecker made the first separation of isotopes which was proved to be obtained. They obtained a partial separation of chlorine of atomic weight 35.46 into two isotopes of weights 35 and 37. A similar separation had been made in 1916 and early in 1917 by Harkins and Turner, but the war made it impossible to determine the atomic weights at that time.

The earliest detection (and determination of the mass) of isotopes by electrical means was entirely accidental. In 1913, J. J. Thomson, by deflection experiments on canal (positive) rays, found that there seemed to be two kinds, instead of one, of neon in a tube which contained this element. Although this is correct, the experiment did not appear to be entirely conclusive to Thomson or his co-workers, as indicated by a letter from the Cavendish Laboratory in 1919. In this year, Aston began an extensive series of determinations of the masses of isotopes in an improved apparatus commonly known as a mass spectrograph, and in a very long series of experiments determined the masses of a very large number of atomic species.

In the experiments of Harkins large quantities of dry hydrogen chloride gas were passed through a long series of porous porcelain tubes (churchwarden pipe stems obtained in Scotland). The ideal diffusion membrane is very thin, to reduce the time in passing through it, and has very fine pores. Later, Harkins and Mulliken found that sheets of filter paper are more efficient than the pipe stems, but the paper membrane could not have been used with hydrogen chloride.

The theory of the separation of gases by diffusion was given in 1896 by Lord Rayleigh and much more completely in 1922 by Mulliken and Harkins. The diffusion method has been used in the separation of the isotopes of uranium. Uranium, a metal which consists of 0.006 per cent 234, 0.7 per cent 235, and 99.3 per cent 238, was separated by the diffusion of its hexafluoride, which is a gas. Unfortunately, the change to the fluoride increases the molecular weights to 348, 349, and 352, but only the two latter need to be considered. Since the lighter molecules move faster than the heavier, more of the former pass through a porous barrier. The relationship for equal kinetic energies ($\frac{1}{2}$ m $v^2$) of the molecules is:

$$\tfrac{1}{2} m_1 v_1^2 = \tfrac{1}{2} m_2 v_2^2$$

or

$$\frac{v_1^2}{v_2^2} = \frac{m_2}{m_1}$$

so

$$\frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}} = \beta$$

which is the enrichment factor, so, for uranium hexafluoride

$$\beta = \sqrt{352/349} = 1.0043.$$

Thus, if a very small amount of the uranium compound passes through a very fine porous wall, it contains, after the diffusion, under ideal conditions, 1.0043 times more uranium 235 than before, or 0.70301 per cent, if the initial percentage is 0.7. It is obvious that the separation is initially made much more difficult by the small percentage of uranium 235 present. The theory of the *increase* in the mean molecular weight ($\Delta$ M) of the heavy fraction is simpler, and is expressed by

$$\Delta M \alpha \frac{(M_1 - M_2)^2 x_1 x_2}{M}$$

Here, $A = (M_1 - M_2)^2 = 3^2 = 9$, which is a somewhat favorable factor for the separation of isotopes. However, M, the mean molecular weight, is about 352 = B, which is very unfavorable, and $x_1 x_2$, the product of the fractions present, $0.007 \times 0.993 = 0.007 = C$, is also extremely unfavorable. Thus, the molecules must pass through a very large number of porous barriers to obtain any considerable separation. When hydrogen chloride is diffused, $A = 2^2 = 4$, $B = 36.46$, and $C = 0.23 \times 0.77 = 0.177$. Here, for hydrogen chloride, only A is less favorable, while B and C are very much more favorable than with uranium as its hexafluoride.

When the percentage of uranium 235 in the light fraction becomes sufficiently high, the magnetic separation becomes more efficient than diffusion. The elec-

tromagnetic method is discussed somewhat fully in the official report and need not be considered here.

## VI. The Neutron

The neutron was discovered in 1932 by Chadwick. This discovery illustrates the advantage of having an idea that a particle exists before attempting to discover it. That a neutron exists was assumed by both Rutherford and Harkins independently early in 1920. This atom was assumed to have a zero charge and therefore an atomic number of zero. Its mass was assumed to be unity or, more definitely, close to that of the hydrogen atom. It was predicted that on account of its zero charge it would pass with practically no resistance through the outer part of atoms, but that it could collide with an atomic nucleus or be captured by it. A bullet may be shot from the muzzle of a rifle at a relatively small velocity, yet it may travel through air for one or two miles. The bullet can go this far, because it pushes the air away from it in its flight and does not pass through the atoms in

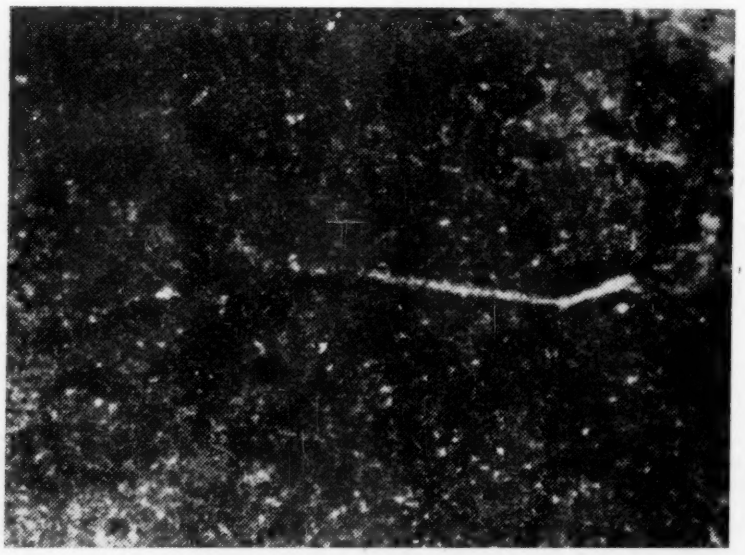

Fig. 2. First neutron found in America. Disintegration of nitrogen 15, the intermediate nucleus formed from nitrogen 14, by the impact of a neutron.

the air. An alpha particle (a helium nucleus) may have an initial velocity as high as 12,000 miles a second. It might therefore be supposed that this particle would travel in air many thousand times farther than a rifle bullet. However, its entire range is only a few inches. This is because the alpha particle does not push the atom in the air aside, but its velocity is so great that there is no time for this to occur. Therefore, it has to go directly through the cloud of electrons in the outer part of each atom which it traverses. On account of the fact that it carries with it a positive charge of 2 or of 1 (after it has picked up a single electron) it attracts these electrons and pulls many of them out of the atoms to which they belong. This takes energy and uses up the kinetic energy of the alpha particle very rapidly. A atom or molecule from which one or more el trons has been taken is a positive ion, and one which electrons have been added is a negative i Thus, the alpha particle in its passage through leaves a narrow line of positive and negative ions, a this line may be considered as the track of the alp particle. A fast proton gives a similar track wh

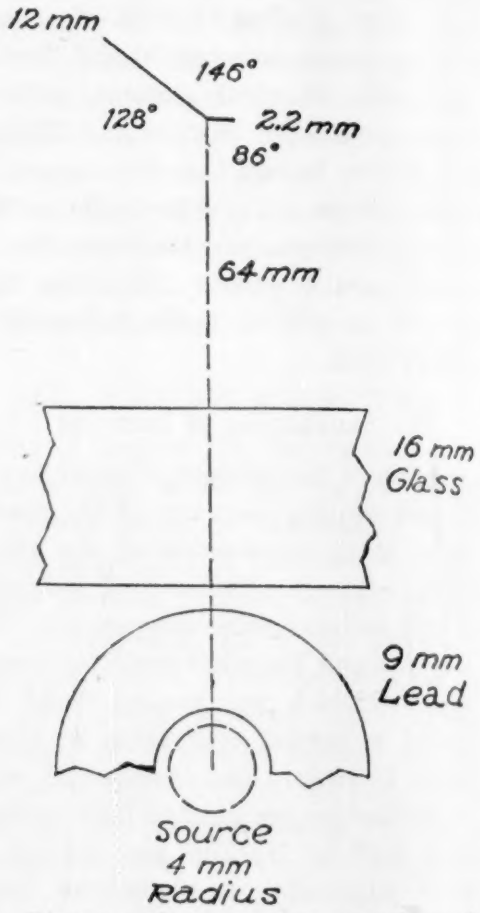


Fig. 3. Diagram of the nuclear transformation show in Fig. 2. The neutron came from the action of a heliu nucleus on beryllium in the source 4.4 mm. in radius. Th passed through 9 mm. of lead, 16 mm. of glass, and, after total range through solids and nitrogen gas of 64 mm., struc and united with a nitrogen nucleus of mass 14. The inte mediate nucleus of mass 15 very quickly disintegrated int a helium nucleus of 12-mm. range and a boron 11 nucleus 2.2-mm. range. The passage of the neutron through 9 m of lead and 18 mm. of glass, including the wall of the glas tube, illustrates the penetrating ability of a neutron.

does not contain so many ions, since the proton ha a charge of 1, which is less than that of the alph particle. Other atoms of the higher charge leave mor dense tracks. Any of these may be made visible if th moist air or other gas through which they have passe is cooled by a sudden expansion and is simultaneously illuminated by a brilliant light. This procedure is usually carried out in a cylindrical chamber, which is a part of the Cloud Track apparatus of C. T. R. Wilson.

Neutrons were obtained in 1930 by Bothe and Becker, when either beryllium or lithium was bombarded by alpha particles, and by Irene Curie and Joliot in 1932. Since neither of these pairs of investigators seemed to be aware that neutrons might

exist, they assumed that very powerful gamma rays were involved and thus failed to discover their existence. Chadwick, however, believed uncharged heavy particles were involved and this was confirmed in 1932 by Feather, who used the Wilson Cloud Track apparatus. This was followed immediately by an even more extensive investigation by Harkins, Gans, and Newson (later also Kamen), who obtained results similar to those of Feather. Since the neutrons given off, for example, when beryllium is bombarded, do not ionize the gas through which they pass, the track is not visible in the Wilson Chamber. How, then, can the neutrons be observed? This is accomplished by means of the tracks of other nuclei which are produced by (1) elastic collections of the neutron with the nucleus; (2) inelastic collections in which the neutron is captured by the nucleus which it strikes. If, for example, this happens to be a nitrogen nucleus, a short track of a boron nucleus and a much longer track of a helium nucleus (alpha particle) are observed to originate at a single point.

From the relations found in these and other photographs of atomic transformations the writer developed the theory of the existence of an intermediate, or compound, nucleus as presented in the introduction, and also in a later section.

## VII. The Valley of Stability

While protons, aside from the effect of their charge, presumably exhibit some attraction for each other at extremely small distances, this is much less than the repulsion between their charges. This is overbalanced in the nucleus by the strong interaction between protons and neutrons. If the number of protons is small (20 or less), at least one neutron per proton is required to stabilize a nucleus. These relations became apparent to the writer in 1921 (*3*), in a paper which considered the effects of the number of protons and neutrons in atom nuclei upon their stability. However, as the number of protons increases above 20, their repulsion becomes so great that the nuclei are not stable unless the number of neutrons increases more rapidly than the number of protons.

The stability of atomic nuclei may be summed up in terms of (1) a general relation between the number of protons and of neutrons in the nucleus, and (2)

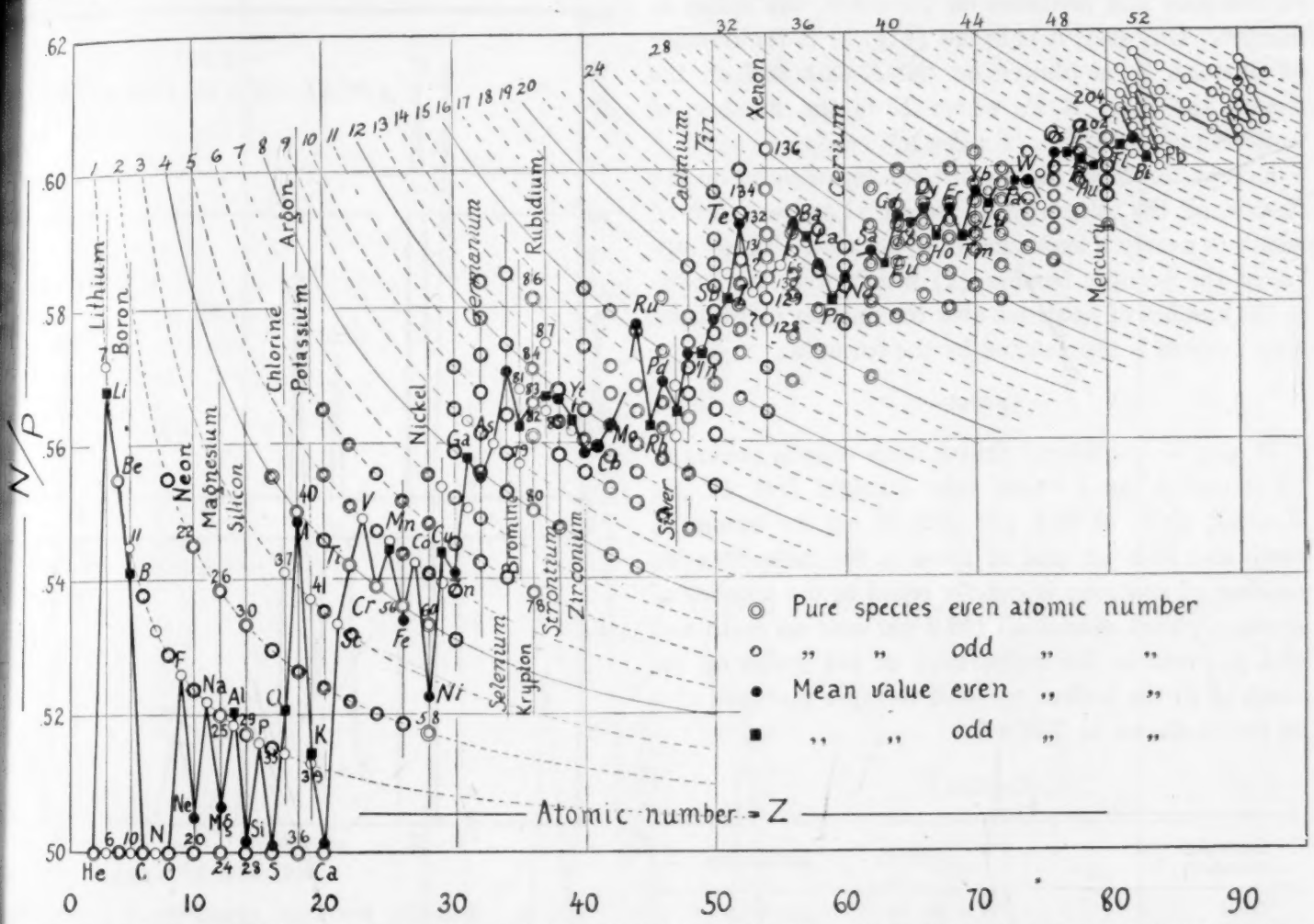


FIG. 4. Relationship between the *number of protons* Z in atomic nuclei and the *ratio of neutrons to total particles* (P = protons plus neutrons). Only stable atoms are represented. The curves, nearly rectangular hyperbolae, are numbered to give the isotopic number of the species of atoms represented. The isotopic number gives the number of neutrons in the nucleus in excess of the number of protons. *Nearly all the atoms in the earth or the meteorites are represented by the short straight line at the bottom of the figure.* In these nuclei the number of neutrons is equal to the number of protons. The positions representing the atomic species indicate in a general way the band of stability. To indicate this properly a 3-dimensional plot is essential.

special relations which involve whole numbers, as outlined in the next section.

The general relation may be considered to be represented by a valley in which the atoms are stable, surrounded by slopes where they are partly or wholly unstable. If considered as a relation between protons on one axis and neutrons on the other, the valley is narrow. However, it is broad (Fig. 4) if the number of protons, Z, is plotted on the X-axis and on the Y-axis the ratio N/P, where N is the number of protons and neutrons (P = Z + N).

Except for those atomic species represented on the X-axis, all the other species lie on 54 curves, each of which is nearly a rectangular hyperbola. These represent the isotopic number (I) which gives the excess in the number of neutrons over the number of protons. Any nucleus is represented by the formula:

$$(pn)_z n_1$$

It may be considered that a deep canyon occurs at (N/P) = 0.5, or I = zero (the straight line of the X-axis), since in 84.5 per cent of all the atoms on earth and 79.0 per cent of those in the meteorites the number of neutrons is exactly equal to the number of protons. That *almost* all (99.9 per cent on earth and 98.4 per cent in the meteorites) of the atoms on the earth or in the meteorites have isotopic numbers of 4 or less is shown in Table 1.

TABLE 1

| Isotopic number | Earth | Meteorites |
|---|---|---|
| 0 | 84.5 | 79.0 |
| 1 | 13.0 | 5.3 |
| 2 | 0.2 | 1.6 |
| 3 | 0.007 | 0.0 |
| 4 | 2.2 | 12.4 |
| Sum ..... | 99.9 ..... | 98.3 |

Thus, the valley is extremely deep at the lowest edge, rises to a ridge at I = 3, gives a deep valley at I = 4 and is shallow above this. Atoms in which N/P is too low for stability must increase N by the conversion of a proton into a neutron by giving off a positive electron. If, however, N/P is too high, a neutron must change into a proton by giving off a negative electron (β-particle).

## VIII. Stability of Atomic Nuclei and the Abundance of the Elements

In 1913 the writer began a statistical study of the atomic weights then known. The results indicated several relations of interest. The atomic weights (actually mean values for the element) were found to be so close to whole numbers for elements 2 to 28 inclusive that several conclusions seemed inevitable as follows:

(1) The masses of the atoms are extremely close to whole numbers, with the exception of that of hydrogen (Whole Number Rule). This was confirmed by Aston in 1919 and later.

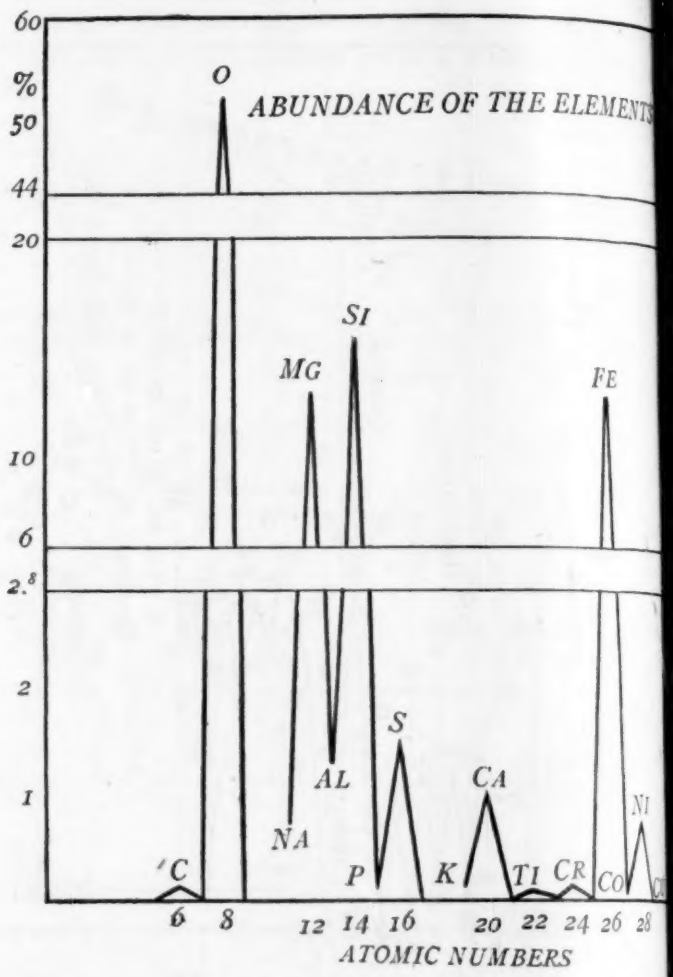


FIG. 5. Exhibits the high abundance of nuclei which contain an even number of protons. The figure gives the abundance in the meteorites. Neon (atomic number 10) and argon (atomic number 18) are gases and have escaped. In the stars, carbon, an element of even number, is extremely abundant as is also neon.

(2) Any considerable departure of the atomic weights (when correct) of the elements from a whole number was taken to indicate a mixture of isotopes. This conclusion was confirmed in the case of chlorine, atomic weight 35.46, by the separation of the element into isotopes.

(3) It was found that for elements of even atomic number above 26 (even number of protons in the nucleus) the atomic weights are no closer to whole numbers than they should be by chance. Thus, for each of these elements there should be many isotopes, while the odd elements were indicated as having only one, or very few, isotopes. Later, this also was confirmed by Aston.

The general theory of nuclear structure advanced at that time by the writer was sufficiently fruitful to give rise to several other predictions, which were verified later.

(4) Thus, the theory predicted that *elements* of even atomic number (P = even) should be much more abundant than those of odd atomic number. When this was investigated it was found that in the meteorites (Fig. 5) the elements of even atomic number are 70 times more abundant than those of odd number, while in the surface of the earth and the sun this ratio is about ten to one. Also, the stars in so far as they have been investigated seem to exhibit a decided preference for elements of even number. Thus, atomic nuclei which contain an even number of protons are much more "stable" than those in which the number is odd.

(5) An even more prominent relation is that in almost all "stable" nuclei the number of neutrons is even (Fig. 6). Thus, in so far as the abundance of atomic species has been determined, 99 per cent of all the atoms in the earth's crust have nuclei which contain an even number of neutrons. This relation became apparent to the writer in 1921, when he developed a formula for all nuclei as follows:

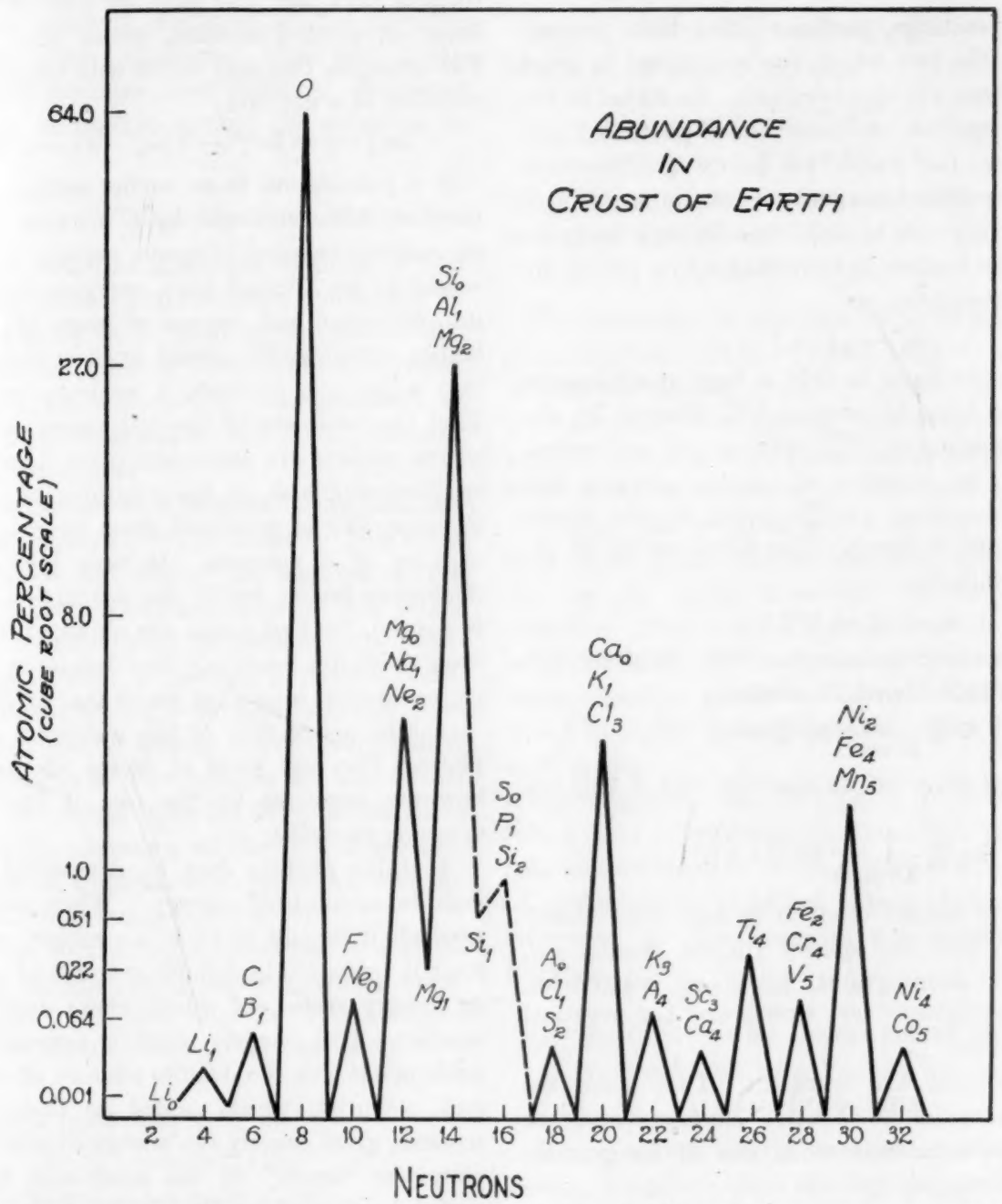


FIG. 6. Illustrates the excessively high abundance of atomic nuclei which contain an even number of neutrons, in comparison with the extremely low abundance when an odd number of neutrons is present. Note the cube root scale and that oxygen 16 (isotopic number equal zero) with the highest peak is about 100 times more abundant than the most abundant set of atomic nuclei for any single odd number of neutrons. The figures attached to the symbols of the elements are the isotopic numbers.

$$(pn)_z n_i$$

in which p is a proton; n, a neutron; $\hat{z}$, the atomic number; and $\hat{\imath}$, the isotopic number. The isotopic number gives the excess in the number of neutrons above that for atoms whose nuclei contain equal numbers of protons and neutrons.

(6) Thus, there are almost no atoms whose nuclei are stable with an odd number of both neutrons and

protons: only about one atom in ten thousand on earth. This is an extremely remarkable relation.

## IX. Fundamental Particles and the Formation of Plutonium

In nuclear reactions, particles other than protons and electrons, the two which are considered to exist inside the nucleus, are also involved. As stated in the last section, negative electrons (or β-particles) are given off from the nuclei of heavy (radioactive) atoms, if the particular species contains more neutrons than corresponds to stability. In such an event a neutron in the nucleus is converted into a proton by emission of an electron, or

$$n_0^1 \rightarrow p_1^1 + e_{-1}^0$$

In such a change there is only a very small loss of mass. By this type of process $U_{92}^{239}$ (formed by the addition of a neutron to $U_{92}^{238}$) changes into neptunium ($N^{239}_{93}$). Then, by emission of another electron this changes into plutonium ($Pu^{239}_{94}$), which is used in one of the two types of bomb. The whole series of reactions is as follows:

$$n_0^1 + U_{92}^{238} \rightarrow U_{92}^{239} + \gamma$$

where γ represents gamma rays. Now, an electron is emitted with a half-life of 23 minutes:

$$U_{92}^{239} \xrightarrow[23\ \text{min.}]{} Np_{92}^{239} + e_{-1}^0$$

Neptunium also gives off an electron with a half-life of 2.3 days:

$$Np_{93}^{239} \xrightarrow[2.3\ \text{days}]{} Pu_{94}^{239} + e_{-1}^0.$$

In general, any second electron is lost more slowly than the first, and the species formed finally, *e.g.* $Pu^{239}_{94}$, when it disintegrates, gives off α-particles. Plutonium disintegrates very slowly and for practical purposes is stable.

Positive electrons are transient. They have the same mass as ordinary negative electrons and are given off from a nucleus when one of its protons changes into a neutron:

$$p_1^{+1} \rightarrow n_1^0 + e_{+1}^0$$

Such positive electrons disappear very rapidly, since, when they meet negative electrons, their mass takes on the form of radiation and no electron is left:

$$e_{-1}^0 + e_{+1}^0 \rightarrow \gamma.$$

The atomic mass of the electron is 0.0005486 or $9.1 \times 10^{-28}$ gram, so, since both electrons disappear, twice this amount of mass appears in the form of radiation of a frequency $2.5 \times 10^{20}$ vibrations per second, which is a wave length of 0.012 A.

Gamma rays (γ-rays), which are practically x-rays of higher energy and thus of higher frequency, are given off very frequently in nuclear transformations. In some cases this is the only "disintegration," by means of which an intermediate excited nucleus changes into its stable form, as with carbon:

$$C_6^{12*} \rightarrow C_6^{12} + \gamma$$

Gamma rays may also play the part of projectiles to form an excited nucleus, which then disintegrates. For example, this may occur with beryllium, with the emission of a neutron:

$$Be\ {}^9_4 + \gamma \rightarrow Be_4^{9*} \rightarrow (Be_4^{8*} + n) \rightarrow 2\ He_2^4 + n_0^1$$

It is pointed out in an earlier section that an alpha particle, when captured by a nitrogen nucleus, gives an unstable (excited) fluorine nucleus of mass 18. At *relatively* low, though high, energies this disintegrates into hydrogen and oxygen of mass 17. However, at higher energies the excited nucleus disintegrates also into a positive electron, a neutron, and oxygen 17. That the products of the disintegration of any compound nucleus are dependent upon its state of energy is illustrated also in the relations of uranium; *e.g.* uranium 239 is produced from uranium 238 by the capture of a neutron. At very high energies this undergoes fission, but if the production of plutonium is desired, the best yields are obtained if neutrons are used which are relatively slow but lie in the resonance region located somewhat above that of thermal energy —that is, above that of the molecules in the atmosphere. The best yield of fission of uranium 235 is, however, obtained by the use of thermal, or low-velocity, neutrons.

A stable nucleus may be considered as having a definite amount of energy. When more energy is present, it is said to be in an excited state. Such a state is restricted to definite amounts of energy, known as energy states, of which there are a very great number. If a particle which is approaching a stable nucleus has just the definite amount of energy, kinetic and potential, which, added to that of the stable nucleus, gives exactly the energy of one of the energy states or "levels" of the compound nucleus which would be formed by the union of the two particles, then the probability of the union of the two particles is extremely high. This phenomenon is known as *resonance*. As the energy departs from that of the energy level, the probability of the union of the two particles decreases rapidly. Different resonance levels have different widths: *i.e.* at some levels the variation of energy for capture (or for emission) is much greater than at others.

It is found that different elements, when used with all of their isotopes present, capture neutrons of certain velocity much more than those which have other velocities. A region of energy in which this capture is more apt to occur is a resonance region of one of the isotopes. For example, cadmium exhibits a very

marked capture of neutrons which are very slow, with energy of 0.01 volt. With silver this rises to 1 ± 0.3 volts; with rhodium, to 3 volts; with iodine, to 200–300 volts; and with bromine, to 100–500 volts. Thus, when neutrons are shot through a thin sheet of any of these elements, neutrons of the energies noted are greatly reduced in number, while most of the neutrons of other energies pass through. Relations of this type may be used to control the reactions in the bomb.

## X. Discovery of the Trans-Uranium Elements

After the completion of the other sections of this paper the new elements 95 and 96 were announced on 16 November 1945,* by G. T. Seaborg, the earlier discoverer of plutonium[3] (late in 1940). The first trans-uranium element, neptunium 239, was produced in May 1940, by E. M. MacMillan and P. H. Abelson, by the following procedure:

By a radiative capture of a neutron in uranium 236 an isotope of mass 239, ($U^{239}$) is formed. This emits a β-particle with a half-life of 23 minutes, giving neptunium of the same whole number mass 239 (since the loss of mass accompanying the emission of an electron is very small). Now, in general, in natural radioactivity the emission of one β-particle is followed by the emission of a second with a considerably longer life. In conformity with this relation the half-life of neptunium 239 was found to be 2.3 days, or 144 times longer than for the emission of the first β-particle. The first isotope of plutonium to be found was not that used in the atomic bomb, but was $Pu^{238}$.

First, $U^{238}$ was bombarded in the cyclotron of E. O. Lawrence by the nucleus of heavy hydrogen (deuteron) of formula $(pn)_1^2$ and mass 2. Two neutrons escape, so the resultant effect is the addition of a proton:

$$U_{92}^{238} + (pn)_1^2 \longrightarrow Np_{93}^{239*} + n_0^1$$

$$Np_{93}^{238*} \longrightarrow Np_{93}^{238} + n_0^1$$

$$Np_{93}^{238} \xrightarrow[2.0\ \text{days}]{} Pu_{94}^{238} + e_{-1}^{0}$$

The isotope of plutonium thus formed emits α-particles with a half-life of about 50 years.

More important is the isotope $Pu_{94}^{239}$ used in the bomb. This is formed by the emission of a β-particle (2.3 days half-life) from the nucleus of the $Np^{239}$ described above.

Recently, as mentioned above, elements 95 and 96 have been discovered by Seaborg and collaborators (R. A. James, L. G. Morgan, and A. Ghiorso) in work at the Metallurgical Laboratory, University of Chicago. Both $U_{92}^{238}$ and $Pu_{94}^{239}$ were bombarded by high energy (40 Mev) helium ions in Lawrence's 60-inch cyclotron, as rebuilt by J. G. Hamilton.

Information as to what isotopes were found has not been released, but it is very simple to indicate what excited compound nuclei are formed.

$$U_{92}^{238} + He_2^4 \longrightarrow Pu_{94}^{242*}$$

If this emits β-particles, then

$$Pu_{94}^{242*} \longrightarrow X_{95}^{242} + \beta$$

$$X_{95}^{242} \longrightarrow Y_{96}^{242} + \beta$$

With plutonium the excited compound nucleus would be formed as follows:

$$Pu_{94}^{230} + He_2^4 \longrightarrow Y_{96}^{243*}$$

The chemistry of elements 93 to 96 is of extremely great interest. At the present time, 97 elements, including the element of atomic number zero (its atoms are neutrons), are known. Of these 1 to 96 have outer electrons and the associated chemical properties, while 0 has no electrons and no chemical properties.

Seaborg has revealed a few of the chemical relations of the trans-uranium elements, whose properties are, on the whole, somewhat similar to those of uranium. They form a transition series, and in this sense resemble the rare earths, but especially the lower numbers of the series are much more easily raised to higher oxidation states (above III) than the rare earths.

Seaborg finds that $10^{14}$ parts of pitchblende contain 1 part of plutonium. From this it may be calculated that there is in the earth's crust about 1 atom of plutonium to 10 billion-billion atoms of the other elements. In this work he was assisted by M. L. Perlman.

## XI. Theory of the Intermediate or Compound Nucleus and the Fission of Uranium and Plutonium

It is pointed out in the introduction that in a nuclear transformation the first step is the formation of an excited nucleus, as follows:

$$P + T \longrightarrow C^* \qquad (1)$$

Then $C^*$ must get rid of its excess energy by some type of change in which it loses energy, so:

$$C^* \longrightarrow D + E.$$

If E is excited, a second disintegration occurs (Fig. 7). For the fission of uranium or of plutonium the first step is the formation of the excited nucleus which is to split into parts. This is done by the addition of a neutron ($n_0^1$), as follows:

$$U_{92}^{235} + n^1 \longrightarrow U_{92}^{236*}$$

$$Pu_{94}^{239} + n^1 \longrightarrow Pu_{94}^{240*}$$

Since the disintegration by fission of one of these is

* Collaborators in the discovery of plutonium: E. M. MacMillan, A. C. Wall, and J. W. Kennedy.

a process of the same type as that of the other, only the fission of $U^{236}$ is considered here.

In its fission the nucleus seems to split into two unequal parts of masses 127 to 154 for the heavier fragment and 115 to 83 for the lighter fragment. However, most of the masses lie between 134 to 144 for the heavier and between 90 and 100 for the lighter fragment. Inspection of Fig. 4 shows that for uranium 236 the ratio of neutrons to total particles in the nucleus is 0.61, while in the range of mass from 134 to 144 even the highest ratios are in general 0.6 or less, and for mass numbers 90 to 100 the highest ratios of any of the isotopes are about 0.584. Thus, if the two atoms formed in the end as the result of any fission have even the highest number of neutrons for stable isotopes, there are about five neutrons to be accounted for; if lower isotopes, more than five.

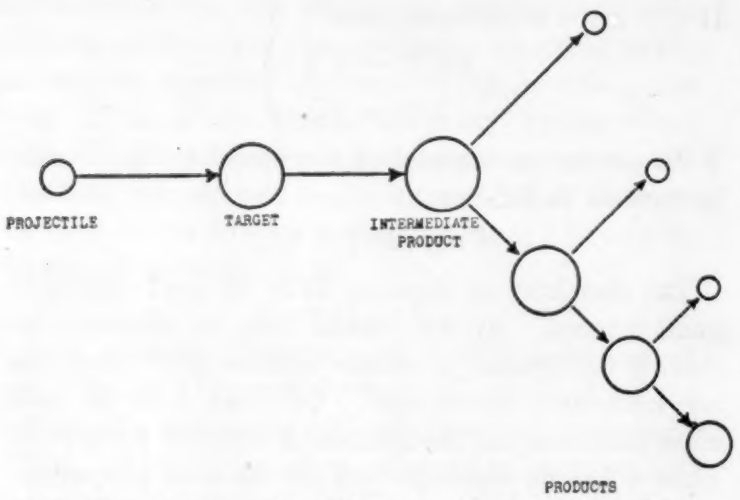


FIG. 7. A nuclear transformation in which several intermediate nuclei are involved.

The process of fission may be considered analogous to what would occur if the water drop in air were to be set into strong vibration. This would result in the separation of the drop into two parts, but initially with a neck, or cylinder, of water between them. This, then, segregates into several minute water droplets. In the fission of uranium 236 it may be assumed that the process is analogous and that the droplets formed are neutrons, 1 to 3 in number. The loss of this number is not sufficient to allow the two atoms formed as fragments to be stable. Therefore, these nuclei must expel neutrons, but the expulsion may be "delayed" for a period of moderate length. Another method of getting rid of extra neutrons is for the neutrons in the nuclei to lose negative electrons, thus converting neutrons in the nuclei into protons. It may be supposed that the "delayed" neutrons observed to be given off after the fission occurs are emitted after the emission of one or more negative electrons, since the life of atoms in electron emission is much greater in general than that for neutron emission. Although the water-drop model is used above to illustrate fission, nuclei in general seem to be more closely similar [illegible] minute crystals.

The history of the discovery of the fission of heav[y] atomic nuclei into two nearly equal parts is of e[x]treme interest but cannot be related fully here. T[he] lightest atoms such as the neutron, the hydroge[n] atom, or the atom of heavy hydrogen have mass[es] higher than their respective whole numbers, in t[he] case of the neutron by 0.9 per cent, and for hydroge[n] of unit mass by 0.8 per cent. The atomic weig[ht] of oxygen is a whole number by definition. As t[he] atomic mass becomes higher, it falls below that of t[he] corresponding whole number with extreme slowne[ss] but when barium of masses 130 to 138 is reached [it] has fallen to about 0.08 units below the whole numbe[r]. Above this, the negative deviation from a whole nu[m]ber becomes smaller, so that, when mercury of atom[ic] weight 200 is reached, it is almost exactly at the who[le] number again (mass 200 = 200.016). Above this, t[he] positive departure from a whole number increas[es] rapidly, and the mass of $U^{236}$ may be given as 236.0[93].

Now, if $U^{236}$ were to split into two parts, it woul[d] lose the excess over a whole number (.093) and als[o] 0.08, the defect in the mass, or 0.173, which is th[e] sum of these. However, on the average, two neutron[s] are lost in the process, and these have an excess mas[s] of 0.018, so that the loss of mass experienced by an[y] 235 grams of uranium used in the bomb would b[e] 0.155. This multiplied by $c^2$ gives $1.4 \times 10^{20}$ ergs, o[r] $3.4 \times 10^{13}$ calories. This amounts to $2.7 \times 10^{20}$ ergs, o[r] $6.6 \times 10^{13}$ calories per pound. The temperature th[at] given by the bomb is many million degrees and th[e] pressure many millions of atmospheres. However, th[e] efficiency is not perfect, since not all of the uraniu[m] or plutonium atoms in the bomb undergo fission, an[d] the temperature is so high that a considerable fractio[n] of the energy may escape as radiation, which, although it gives pressure, is relatively ineffective as compared with the motion of the molecules.

Fermi became interested in the work on the disintegration of light atoms by neutrons, as presented in a paper by the writer at the Conference on Nuclear Physics at the University of Chicago in June 1933. In this paper Harkins, Gans, and Newson reported the discovery of the first artificially radioactive material ever produced, a nitrogen isotope of mass 16. A year later Joliot and Curie obtained a nitrogen isotope of mass 13, which they proved to be radioactive. Fermi had available at the University of Rome about fifty times more radium than was available at the University of Chicago, and was thus able to make a rapid survey of the effects of neutrons on a very large number of the heavier elements. This work gained him the Nobel Prize, which he merited on account of

e discovery of the effects of slow neutrons and his lier work in statistical mechanics. However, very fortunately, the prize was granted for the discovery the trans-uranium elements 93, 94, 95, and 96, the covery of which is described in Section X of the esent paper. What Fermi had actually found was e fission of uranium.

In all disintegration reported before 1939, one of e products was always a very light atom, for example, hydrogen of masses 1, 2, or 3, a neutron of ss 1, or helium of mass 4 (or 3). In January, 39, however, Hahn and Strassmann described a petition of Fermi's experiments on uranium. They tained evidence, from the chemical nature and radioive periods of the products, that one of the atomic ecies produced was barium with an atomic mass and mber not far from half that of the uranium which isintegrates. Immediately after this, Frisch and iss Meitner pointed out that this constituted the scovery of an entirely different type of nuclear reacon, in which the intermediate or compound excited ucleus splits into two parts of nearly equal mass.

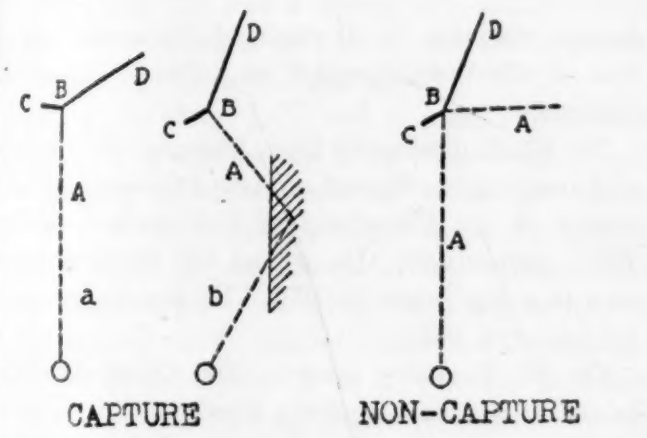


FIG. 8. Formation of an intermediate excited nucleus by apture of a neutron. In *b* the neutron is first deflected by n elastic collision with the nucleus of an atom. The right-and section of the figure represents what would occur if, *ccording to the earlier ideas*, a disintegration were to occur y noncapture. *However, such a disintegration has never een found.*

Very shortly after this, numerous experiments by various investigators, Szilard, Zinn, Joliot, Halban, and Kowarski, combined to show that in each fission from one to three neutrons are liberated. This has been shown in an earlier section to agree with the relations presented in Fig. 4. However, it should be recognized that there is a second mechanism by means of which neutrons can disappear from an atomic nucleus, since, as shown earlier, when a negative electron is emitted by a nucleus a neutron in that nucleus is changed into a proton. The emission of negative electrons in this way is designated as artificial radioactivity, and the artificial radioactivity which occurs after the fission of a heavy nucleus is extensive.

During the years 1926–36 the writer obtained evidence, partly by experiment and partly from the literature, that the intermediate, or compound, nucleus is formed in all cases as a preliminary to disintegration. One of the first steps taken by Harkins and Gans in 1934 was to show that those disintegrations caused by neutrons assumed by members of the staff of the Cavendish Laboratory to occur by noncapture actually occur by capture (Fig. 8). By the development of a relativistic equation for disintegration by noncapture it was shown:

(1) That in none of the events assumed to occur in this way had there ever been enough energy to give a disintegration of this type. The simple form of this equation is presented here merely to show that the changes of mass involved in a disintegration must be considered:

$$V_A = \frac{\{M^2 + 2m_A[E_C + E_D + c^2(m_C + m_D - m_B)]\}}{2m_A M \cos \alpha}$$

Here $V_A$ is the velocity of the projectile; M is the momentum; E is the kinetic energy; m, mass; c, the velocity of light; and A, B, C, and D are the nuclei involved.

(2) That the energies of the neutrons which were supposed to give noncapture disintegrations were found to lie on the same curve as those known to be of the capture type.

(3) That an intermediate compound nucleus is formed is shown clearly in events in which neutrons and protons are both given as the final products in two types of disintegration obtained from the same initial projectile and target. For example, if an intermediate, or compound, nucleus is formed by the addition of the helium nucleus to $N^{14}$, very few protons are emitted until the alpha particles have a somewhat high velocity, after which the number of protons emitted rises very rapidly with the velocity of the alpha particle and then quickly reaches a constant value, which, however, soon begins to decrease. Just as this decrease begins to appear, neutrons are found to be given off by the disintegration. The number of neutrons now increases at the same rate as the yield of protons decreases, which shows most clearly that in such transformation there is no direct coupling between the initial alpha particle and the protons and neutrons formed as the final products of the disintegration. The formation of protons and of neutrons are thus disintegrations of the compound nucleus, which compete with each other, the increase in one giving a decrease of the other.

One of the most prominent properties of the neutron, due to its absence of charge, is that it can

pass through an enormous number of other atoms without deflection, unless it strikes a nucleus. Since, on the average, about two neutrons are emitted by each fission and only one is needed to produce it, and since, in addition, the reaction is exceedingly fast, the number of neutrons and also the number of fissions increases with extreme rapidity, provided no neutrons escape. However, unless the body is moderately large, so many neutrons escape that, on the average, less than one of the neutrons produced by a fission is effective in uniting with a nucleus to give another fission, so the reaction dies out. If the body is larger than this (known as the critical volume highly dependent upon the shape), the reaction proceeds. In such a case the term, chain reaction, has been employed, although this is somewhat different from the prior use of this term in chemistry.

The writer realized not very long after the beginning of the development of his general theory of nuclear transformation, in 1926, that the complete theory is of the quantum-mechanical type. Such an enlargement of the theory was developed in 1937 by Bohr and Kalckar (*2*). However, this was not done until the point of view of nuclear physicists in general was changed by experimental evidence, which demonstrated that the *primary* process is the formation of a nucleus, rather than its disintegration.

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# *Obituary*

## Thomas J. Maney
### 1888-1945

Last 12 October marked the passing of T. J. Maney, chief in pomology at Iowa State College. His death occurred at Rochester, Minnesota, where he had undergone an operation.

Maney was born at Geneva, New York, on 24 April 1888. He gained his inspiration for horticulture under the tutelage of Professor S. A. Beach and graduated from Iowa State College in 1912. He was employed by the college immediately following his graduation, in which relationship he continued for the past third of a century. He served as chief in pomology at this institution since 1917. His special field was hardy stocks for the pomaceous fruits. His genial fellowship and keen Irish wit will be missed by his college associates.

Mr. Maney is survived by his wife and three sons, one of whom is in the Army Air Corps.

A. T. ERWIN

*Iowa State College*

## Bruce Lawrence Clark
### 1880-1945

Dr. Bruce Lawrence Clark, associate professor of paleontology, emeritus, of the University of California and one of the country's outstanding authorities on invertebrate paleontology, died on 23 September 1945 at his home, 916 Euclid Ave., following a six-month illness. His death will be mourned by hundreds of his former students in all parts of the world, who held him in affectionate regard as a friend as well as an instructor.

Dr. Clark graduated from Pomona College in 1908 and received his Master of Arts degree and his Ph.D. degree at the University of California in 1909 and 1913, respectively. He joined the university faculty as a teaching fellow in 1909. He became an associate professor in 1923.

On the Berkeley campus, Dr. Clark developed a school of graduate students who went out to all parts of the world to develop the vast oil fields in Arabia, Sumatra, Java, Borneo, Colombia, Venezuela, and Mexico. He himself traveled extensively in Europe and Mexico visiting other scientists in his field.

His principal interest was in the invertebrate fossils of the Pacific Coast and he had recently discovered radiolarian deposits from the Eocene period in the region of Mount Diablo. He was a member of the American Association for the Advancement of Science, the Paleontological Society, the Geological Society of America, the California Academy of Sciences, the Faculty Club, and the First Congregational Church of Berkeley.

Dr. Clark was born in Humboldt, Iowa, on 29 May 1880. He is survived by his wife, Mrs. Delia E. Clark, a daughter, 2d Lt. Elizabeth Clark of the Army Nurse Corps at DeWitt General Hospital at Auburn, California, and a son, Bruce E. Clark, CM1/c USNR, now home from Okinawa.

CHARLES L. CAMP

*University of California, Berkeley*

# Technical Papers

## The Effect of B-Pyracin and the *Lactobacillus casei* Factor Upon Hemoglobin Regeneration Following Hemorrhage[1,2]

M. L. Scott, L. C. Norris, and G. F. Heuser
*Agricultural Experiment Station and School of Nutrition, Cornell University*

Recently Scott, Norris, Heuser, and Bruce (*4*) reported that the macrocytic hypochromic anemia which develops in chicks fed a purified diet is prevented by administration of the crystalline *Lactobacillus casei* factor (LCF) of Hutchings, Stokstad, Bohonos, and Slobodkin (*2*) together with either the lactone of 2-methyl-3-hydroxy-4-hydroxymethyl-5-carboxypyridine (α-pyracin lactone) or the isomeric 4-carboxy lactone (β-pyracin lactone).[3] Kornberg, Tabor, and Sebrell (*3*) have shown that the crystalline LCF of Hutchings and associates (*2*) has a preventive and corrective action on hemorrhagic anemia in rats fed a purified diet containing succinyl sulfathiazole.

Since, in the chick, LCF and pyracin appear to be concerned in hematopoiesis under conditions of malnutrition, the question arose as to whether or not injections of these factors might speed up hematopoiesis in times of great need, as for instance, after severe hemorrhage, even when the subjects are receiving a good diet. Experiments were conducted, therefore, to determine if it is possible to hasten hemoglobin regeneration, following severe hemorrhage, by intramuscular injections of LCF and β-pyracin. The results of these experiments are presented in this report.

Three different experiments were conducted using a total of 34 White Leghorn hens in active egg production. Each hen was kept in an individual wire cage in a heated room and fed a commercial diet throughout the experiment. The hens were rendered anemic by withdrawal of blood from the heart with a Luer's syringe. The amount withdrawn was calculated to be approximately one-third of the hen's total blood supply. The blood withdrawal had no effect upon the rate of egg production.

After bleeding, the hens in each experiment were separated into four groups. Group 1 acted as the control and received no therapeutic treatment. Group 2 received 50 γ of β-pyracin[4] per hen, by intramuscular injection, 24 hours after bleeding and subsequently every 24 hours until termination of Experiments 1 and 2, and until the fourteenth day of Experiment 3. Similarly, Group 3 received 50 γ of LCF,[5] and Group 4 received 50 γ each of β-pyracin and LCF per hen per day.

Hemoglobin values were determined for each hen before the experiments were started. Hemoglobin determinations were also made just prior to injection, 24 hours after bleeding, and, in like manner, daily thereafter until the injections were discontinued.

TABLE 1

HEMOGLOBIN VALUES OBTAINED IN HENS ADMINISTERED B-PYRACIN AND *Lactobacillus casei* FACTOR (LCF) AFTER HEMORRHAGE

| Treatment | No. hens per lot | Hemoglobin before bleeding grams/100 cc. | Hemoglobin after bleeding by 24-hour intervals grams/100 cc. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| *Experiments 1 & 2 (Preliminary)* | | | | | | | | | | | |
| Control ... | 6 | 8.6 | 5.7 | 6.4 | 5.6 | 6.2 | 6.4 | 6.7 | 6.8 | 7.3 | .. |
| β-pyracin . | 5 | 8.2 | 5.7 | 5.6 | 6.2 | 6.8 | 7.0 | 8.0 | 7.7 | 8.2 | .. |
| LCF ..... | 5 | 8.1 | 5.9 | 6.2 | 6.6 | 6.5 | 7.1 | 7.6 | 7.9 | 8.5 | .. |
| β-pyracin + LCF ... | 6 | 8.6 | 5.7 | 6.1 | 6.6 | 7.4 | 7.8 | 9.0 | 9.4 | 9.7 | .. |
| *Experiment 3* | | | | | | | | | | | |
| Control ... | 3 | 7.5 | 4.5 | 4.4 | 4.8 | 4.2 | 5.4 | 5.6 | 5.3 | 5.8 | 6.0 |
| β-pyracin . | 3 | 7.5 | 4.6 | 5.6 | 6.5 | 7.1 | 6.8 | 6.7 | 6.5 | 8.1 | 8.0 |
| LCF ..... | 3 | 7.7 | 4.9 | 5.6 | 5.9 | 6.4 | 6.4 | 7.5 | 7.2 | 7.9 | 7.5 |
| β-pyracin + LCF ... | 3 | 7.9 | 4.9 | 5.6 | 6.1 | 7.1 | 7.3 | 8.1 | 8.3 | 8.9 | 9.7 |

The "pre-bleeding" hemoglobin values obtained on these experiments were lower than the value of 9.8 grams per 100 cc. of blood reported to be normal for the hen by Dukes and Schwarte (*1*). We have obtained values on hens receiving the same diet, but not in active egg production, which are in agreement with the value reported by these workers.

[1] This work was aided by grants to Cornell University by the Western Condensing Company, San Francisco, California, and the Wyeth Institute of Applied Biochemistry, Philadelphia, Pennsylvania, and was conducted in the nutrition laboratories of the Department of Poultry Husbandry. The paper was submitted in July 1945.
[2] The technical assistance of R. F. Ball is gratefully acknowledged.
[3] Unpublished studies conducted in this laboratory, together with the data presented here in Experiment 3, show that both the acid and the lactone forms of these compounds are active, nutritionally. Therefore, due to its connotation, the name pyracin will henceforth be applied to the acid forms, while the lactone forms will be referred to as pyracin lactones.
[4] We are indebted by Merck and Company, Rahway, New Jersey, for the crystalline β-pyracin lactone used in Experiments 1 and 2. The lactone was converted to β-pyracin for use in Experiment 3 by refluxing 5 mg. in 20 cc. of 0.05N NaOH for 15 minutes.
[5] We are indebted to Dr. E. L. R. Stokstad and Dr. B. L. Hutchings, of Lederle Laboratories, Pearl River, New York, for the crystalline *Lactobacillus casei* factor used in these studies.

The results of the hemoglobin determinations which are presented in Table 1 show that the administration of either β-pyracin or LCF alone is of some value in hastening the regeneration of hemoglobin after severe hemorrhage, but that the administration of both these factors together is markedly more effective, causing a return of the hemoglobin level to the "pre-bleeding" value in five to six days, whereas in the hens receiving no treatment only a slight increase in hemoglobin level was observed in that length of time. Furthermore, the hemoglobin level in the hens receiving both β-pyracin and LCF continued to rise in all experiments and reached the normal level in eight to nine days, while the controls showed an increase in hemoglobin of approximately 1.5 grams per 100 cc. of blood in the same period of time.

In Experiment 3, the hens were held after the vitamin injections were discontinued and periodic hemoglobin determinations were made in order to ascertain the ultimate effect of the removal of approximately one-third of the blood supply. The results are presented in Fig. 1. The results show that in all cases

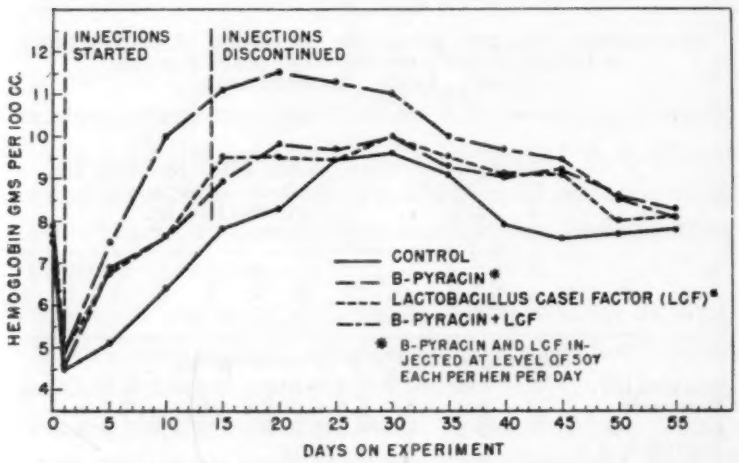


FIG. 1. Effect of injected β-pyracin and *Lactobacillus casei* factor upon the rate of recovery from hemorrhagic anemia.

the hemoglobin levels rose above the "pre-bleeding" values and then declined to approximately the original level. The rate of increase was much more rapid and the level reached was higher in the lot receiving both β-pyracin and LCF than in the other lots. In this lot and the lots receiving β-pyracin and LCF singly, the higher hemoglobin levels were maintained for some time before declining. The rise in hemoglobin levels above the "pre-bleeding" values, which was observed in all lots, may possibly be explained by an overcompensatory activity of the hematopoietic organs under conditions of extreme demand.

## SUMMARY

In severe experimental hemorrhagic anemia in hens, the injection of β-pyracin and *Lactobacillus casei* factor, alone and in combination, was found to hasten the regeneration of hemoglobin. When these factors were administered together, however, the rise in hemoglobin was much more rapid and the level reached was higher than in the lots administered the factors alone.

The hemoglobin levels in the control lots rose above the "pre-bleeding" values and then began an almost immediate decline to approximately the original level. In the lots receiving β-pyracin and *Lactobacillus casei* factor, alone or in combination, the hemoglobin levels also rose above the "pre-bleeding" values but were maintained for some time after injections were discontinued before declining to the original values.

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## The Site of Action of DDT in the Cockroach[1]

KENNETH D. ROEDER and ELIZABETH A. WEIANT
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Yeager and Munson (*4*) have obtained indirect evidence that DDT (*1*-trichloro-2,2-bis(*p*-chlorophenyl)-ethane) may act on motor nerve fibers of the cockroach, raising their irritability until spontaneous discharges result in muscle twitches. Others have confirmed this, observing the twitching which occurs in amputated DDT-treated legs.

If an emulsion[2] containing 5 μg. DDT is injected into the body cavity of an adult cockroach (*Periplaneta americana*) weighing 1.0 to 1.5 grams, the insect shows typical symptoms of poisoning within 5 or 10 minutes. Briefly, the symptoms consist of coarse clonic spasms of the trunk and appendicular muscles and increased but initially well-coordinated activity. Within a few hours the spasms become continuous and the insect is unable to stand, although the legs may continue to twitch feebly for 48 hours.

The dose producing tremors within 5 to 10 minutes is in the neighborhood of 5 to 10 mg./kg. If it is assumed that DDT is distributed evenly among the body tissues, the toxic concentration at the site of action must be approximately 5 parts per million. Even if DDT is selectively accumulated in certain

[1] The work described in this paper was done under a contract, recommended by the Committee on Medical Research, between the Office of Scientific Research and Development and Tufts College.

[2] Twenty ml. of an oil solution (petrolatum mineral oil, 90.5 per cent; oleic acid, 8.5 per cent; and DDT, 1.0 per cent) is passed through a hand emulsifier with 80 ml. of an aqueous solution (insect saline, 99.0 per cent; triethanolamine, 1.0 per cent). The emulsion minus DDT had no effects on cockroaches.

issues, it seems improbable that the toxic concentration at the site of action is more than 10 times greater or less than this figure. The following experiments were carried out in order to discover a site of action sensitive to a direct application of DDT in an approximate concentration of 0.5 to 50 ppm.

*Motor nerves and muscles.* Yeager and Munson found that the injection of a 10-per cent solution of DDT in corn oil locally into the leg of a roach, or into the region of the ganglion of the same segment, produced twitching in the leg muscles within 5 to 10 minutes even after the motor nerves had been severed medial to the injection site. If DDT emulsion (1,600 ppm DDT) is applied directly to the exposed, intact internal ventral muscles of the cockroach after removal of the abdominal ganglia, a series of isolated and often partial contractions of the individual fibers can be observed. These contractions were noted only one to three hours after exposure to emulsion containing 1,600 ppm DDT. In view of the times of onset and high concentration of DDT necessary, it seems doubtful that the direct action of DDT on muscles or on the peripheral stumps of motor nerves can account for the symptoms observed in the intact insect.

*Central nervous system.* Since decapitation or separation of the body segments causes no decrease in DDT tremors, no specific nerve center can be affected. To determine whether DDT has a general excitatory effect on the central nervous system, the thoracic ganglia were dissected in saline and mounted on silver electrodes. The spontaneous electrical activity was amplified and counted electrically over continuous periods of many hours. This method has been used previously to study the central action of excitant and depressant drugs and ions (*3*). Application of solid DDT crystals, 2 per cent DDT in mineral oil, and DDT in emulsion (1,600 ppm) had no detectable effect on the level of spontaneous activity. In view of the concentrations used, the central action of DDT, if any, is of no significance in the genesis of typical DDT tremors.

*Sense organs.* Silver electrodes were placed in contact with an exposed section of the ventral nerve cord of an otherwise intact cockroach. Potentials were fed to a Grass amplifier and recorded with a cathode-ray oscilloscope and camera. Impulses were also counted electrically and monitored with a loudspeaker. The number of impulses per second became relatively constant except during struggles of the insect. If an effective dose of DDT was injected, the number of impulses per second increased 700 per cent as the typical symptoms of poisoning developed. Sectioning the cord above and below the site of the electrodes revealed that the DDT-induced impulses were in ascending fibers. Since the ganglia themselves are not apparently affected by DDT, the ascending impulses must be sensory in origin.

To obtain direct evidence of a sensory effect, the large crural nerve in the metathoracic segment was exposed from its root at the ganglion to the point where it enters the coxa. This nerve is designated as nerve 5 by Pringle (*1*) who showed by physiological methods that it contains afferent fibers from the campaniform sensilla and the hair sensilla in the leg, and a few efferent fibers to the muscles of the coxa. Using a manipulator, two silver electrodes were placed below the nerve between the ganglion and coxa. The electrode nearest the ganglion was pinched tightly around the nerve to crush it at this point. This prevented the nerve from slipping off the electrodes and rendered the afferent impulses monophasic. To eliminate any possibility of motor activity the ganglion was removed, and all other nervous connections with the leg were severed.

Normal electrical activity in the afferent fibers consists of a steady asynchronous series of axon spikes, which is replaced by a complex high-frequency burst of impulses if the leg is moved passively or the coxa and femur are subjected to torsion (*1*). The electrical picture is similar but somewhat simplified if the distal third of the femur is amputated. If DDT emulsion is injected into the cut end of the femur so that the solution passes completely through the leg, there is an immediate and striking change in the electrical activity. In place of the random spikes, a series of impulse trains appears and persists for hours. Each train seems to involve a single fiber which fires repetitively at a frequency of 300 to 400 spikes per second. The train declines slightly in frequency and dies out in 0.1 to 0.5 seconds. The spike height in each train is constant, indicating the involvement of a single axon, although a number of different trains may occur simultaneously. Comparison with normal oscillograms suggests that while the untreated sense cell discharges a single spike at various intervals, under the influence of DDT each single spike is replaced by a short train, likewise repeated at intervals. Even at the height of the DDT-induced discharge no spontaneous movements of the leg were detected in well over 100 preparations and the increased electrical activity seems to be confined to the afferent fibers.

Trains appear in the afferent fibers when solutions containing as little as 0.01 ppm DDT are perfused through the leg. Effects have been obtained with diluted DDT emulsion, suspensions of DDT made by a series of saline dilutions from a 1-per cent solution of DDT in ethyl alcohol, and a saturated aqueous solution of DDT in saline made by allowing saline to stand in contact with pure DDT crystals overnight

at 22° C. The time interval between perfusion and the appearance of trains is related to the DDT concentration perfused (Table 1), and comparison of the figures suggests that the DDT concentration in the aqueous solution was between 0.1 and 0.01 ppm. Although the trains take longer to appear at very low concentrations, they may be marked and persistent.

TABLE 1

| | Diluted emulsion | | | DDT suspension in saline | | | | Saline saturated with DDT |
|---|---|---|---|---|---|---|---|---|
| DDT in ppm | 16.0 | 1.6 | 0.16 | 10.0 | 1.0 | 0.1 | 0.01 | ? |
| Individual times (in minutes) from perfusion to appearance of trains | 3.0 | 4.0 | 16.0 | 3.0 | 10.0 | 13.0 | 43.0 | 20.0 |
| | 7.0 | 8.0 | 9.0 | 2.0 | 3.0 | 21.0 | 52.0 | 42.0 |
| | | | 13.0 | 3.0 | 2.0 | 32.0 | 36.0 | 35.0 |
| | | | 25.0 | 4.0 | 12.0 | 19.0 | 32.0 | 12.0 |
| | | | | 3.0 | 10.0 | 23.0 | 27.0 | 30.0 |
| | | | | | 16.0 | 31.0 | 31.0 | |
| | | | | | 18.0 | | 29.0 | |
| | | | | | 17.0 | | 32.0 | |
| | | | | | 9.0 | | | |
| Av. times | | | 16.0 | 3.0 | 9.6 | 23.1 | 35.2 | 27.8 |

The sensitivity of the sensory response is such that the DDT concentrations reached within the body of a cockroach receiving the minimum lethal dose would be more than sufficient to generate similar trains of impulses in the afferent nerves. It is concluded that in the cockroach the tremors characteristic of DDT poisoning are due to an intense and patternless bombardment of the motor neurones by trains of impulses originating in sensory endings.

It has not been possible to identify the sensory structures upon which the DDT acts. Progressive amputation of the leg reveals that both normal electrical activity and DDT trains disappear if the trochanter is removed, although a considerable length of nerve 5, including several motor branches, remains intact in the coxa. Removal of the trochanter would eliminate all the groups of campaniform sensilla described by Pringle, and the general impression gained is that the proprioceptive sense organs are the structures in which the DDT trains originate. A similar series of trains can be obtained if DDT is injected into the cut cercus, and the electrical activity in the cercal nerve is recorded. The DDT trains are much less marked in this nerve and are somewhat masked by a large, spontaneous background of electrical activity which seems to be unaffected by DDT. Although campaniform sensilla are located on the cercus, they are greatly outnumbered by hair sensilla sensitive to air currents and sound vibrations (*2*). This suggests that DDT does not have its characteristic effect on all sensory structures, but acts to some extent specifically on a particular group of sense organs, as yet unidentified.


## Summary

(1) Although DDT undoubtedly affects motor nerves and muscle fibers in concentrations greater than 1,000 ppm, this action cannot be directly responsible for the clonic tremors in the DDT-poisoned cockroach which can be produced by internal concentrations of the order of 5 ppm.

(2) DDT has no significant action on the cockroach central nervous system.

(3) DDT emulsion perfused through the leg of the cockroach in concentrations as low as 0.01 ppm causes the appearance of a series of high frequency trains of axon spikes in the afferent fibers.

(4) It is concluded that the tremors characteristic of DDT poisoning are due to an intense afferent bombardment of the motor neurons.


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# Molecular Weights and Other Properties of Viruses as Determined by Light Absorption


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Virus solutions exhibit visible opalescence due to light scattered by the virus particles, and this results in a decrease in light transmission. It can be shown by an application of Einstein's theory of light-scattering of mixtures (*1*) that the molecular weight, M, of uniform spherical particles, small compared with the wave length of light, $\lambda$, is given for dilute solutions by the expression $M = 1.69 \times 10^{22} \frac{D\lambda^4}{c\left(\frac{\partial n^2}{\partial c}\right)^2}$, where c is the concentration of the particles expressed in grams per milliliter of solution, D is the optical density (the absorption coefficient divided by 2.303 for a cell of 1 cm. thickness) of the solution, and n is the index of refraction of the solution. Since $\frac{\partial n^2}{\partial c}$ is nearly equal to $2n_0\left(\frac{n-n_0}{c}\right)$, where $n_0$ is the index of refraction of the medium, the latter expression can be used. Therefore, it is possible to secure molecular weight values if, for dilute solutions, the change in optical density with wave length and the indices of refraction of the solvent

and solutions are known. In the present experiments the indices of refraction were determined by means of the Zeiss dipping refractometer, and the light absorption of the solutions was measured in a spectrophotometer at various wave lengths and concentrations. From the slope of the straight-line portion of the curve of D *versus* $\frac{1}{\lambda^4}$ extrapolated to infinite dilution and from the index of refraction of the solution, the molecular weight of the particles in solution is obtained.

The method just described was used in studies with two virus preparations known to possess quite different particle sizes. One of these was the PR8 strain of influenza virus, which has been found to consist of particles about 100 mμ in diameter (*3*), and the other was tomato bushy stunt virus, which has been found to consist of particles about 26 mμ in diameter (*7*). The influenza virus was obtained from infectious allantoic fluid of the developing chick embryo and was purified by a combination of the methods of adsorption on, and elution from, chicken red cells and differential centrifugation recently described by Knight (*2*). The bushy stunt virus was obtained from diseased *Datura stramonium* plants and purified by differential centrifugation as described by Stanley (*6*). The results for aqueous solutions of the two highly purified virus preparations are given in Figs. 1 and 2. The absorption, expressed in terms of the optical density, D, is referred to water as the zero value. For longer wave lengths, D is linear in $\frac{1}{\lambda^4}$, indicating that the absorption is due to Rayleigh light scattering. For shorter wave lengths, where the influenza virus particles are comparable in dimensions with the wave length, there is a decrease in scattering with a deviation from Rayleigh's law as predicted by a theory of Mie (*4*). In the case of the much smaller particles of bushy stunt virus, where the particles are small compared with the shorter wave lengths, there is an increase in absorptions above that of the Rayleigh law

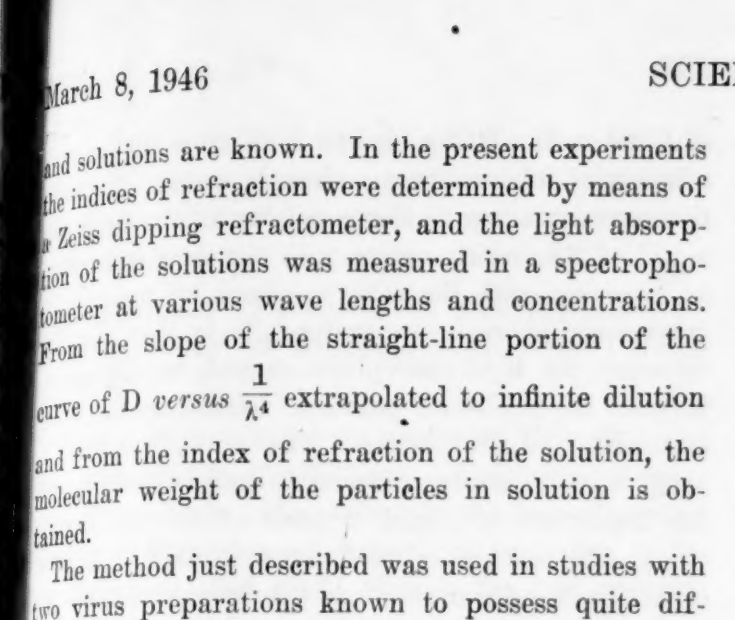


FIG. 1. Light absorption of aqueous solutions of influenza virus as a function of inverse fourth power of the wave length.

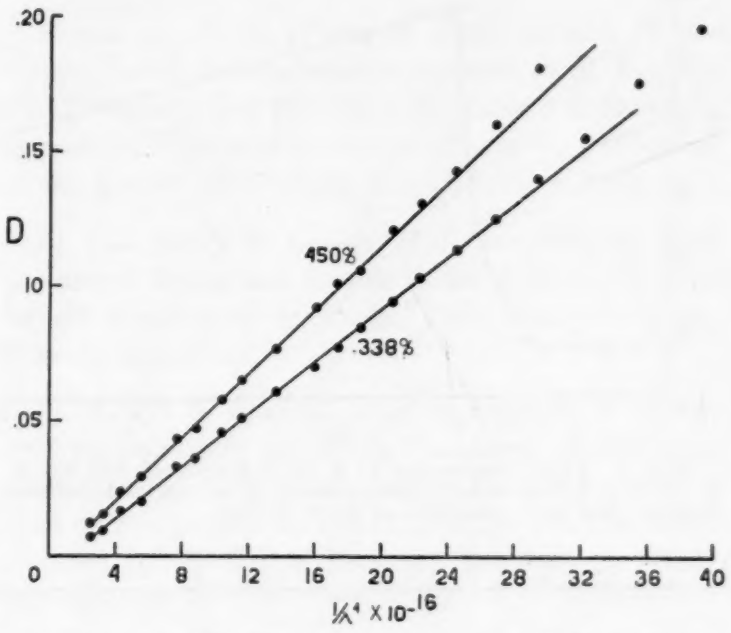


FIG. 2. Light absorption of aqueous solutions of tomato bushy stunt virus as a function of inverse fourth power of the wave length.

because of the high percentage of nucleic acid in this virus (*6*). This component has an absorption spectrum which extends into the visible region.

From the slopes of the straight-line portion of the curves of D *versus* $\frac{1}{\lambda^4}$ for influenza virus and bushy stunt virus, shown in Figs. 1 and 2, and from the indices of refraction of the virus solutions, molecular weight values of 322 million and 9.0 million, respectively, can be calculated. In this method no assumptions need be made about the percentage of hydration of the particles. Lauffer and Stanley (*3*) found the density of influenza virus to be about 1.1. Using this density and the value of the molecular weight of influenza virus determined by the light absorption method, a diameter of 97 mμ is obtained. This value agrees well with estimates of the size of the virus obtained in ultracentrifugation and electron microscope studies (*6*). The molecular weight of bushy stunt virus obtained from the light absorption method agrees well with estimates made by Neurath and Cooper (*5*) and by Stanley and Lauffer (*7*) from ultracentrifugation and diffusion studies.

The light-scattering, and therefore light-absorptive, powers of solutions are very sensitive to changes in particle size, shape, and interaction. For example, the method was used to determine the isoelectric point from the point of maximum coagulation of the virus

particles. A typical curve is illustrated in Fig. 3, which shows the absorption as a function of volume of 0.001 molar HCl added to 5 cc. of a 0.2-per cent solution of tobacco mosaic virus in water. The solution corresponding to the maximum in the curve has a pH of 3.9, which agrees with the isoelectric point as measured with the same solutions by means of a microelectrophoresis apparatus. It is also possible, by using the light-absorption method, to distinguish between the isoelectric points of tobacco mosaic virus and many of its strains. The optical method is being used to study irreversible polymerization and the formation of liquid crystals of tobacco mosaic virus. The method seems to show promise in studies on antibody-antigen reactions involving viruses as the antigens.

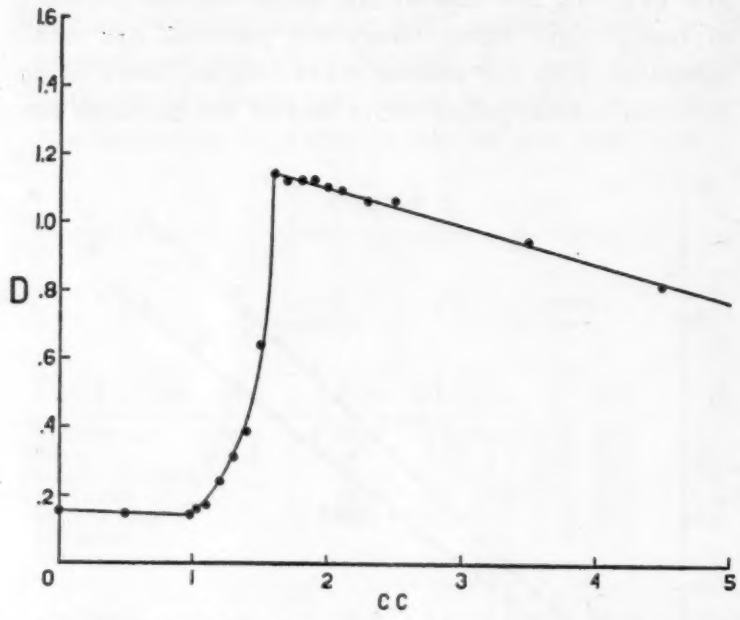


FIG. 3. Light absorption at a wave length of 400 mμ of 5 cc. of a 0.2-per cent aqueous solution of purified tobacco mosaic virus upon addition of 0.001 M HCl.

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# *News and Notes*

## AAAS Meeting Notes

*The Council on Methodology of Science* under the chairmanship of Paul Weiss, University of Chicago will hold a Friday morning session, 29 March, 9:30 A.M. in private dining room 6, Jefferson Hotel. A group of invited scientists will discuss some of the emerging problems which, with the rapid expansion of scientific domain, confront investigators, educators, editors, and administrators. The discussion will center on such subjects as the relation between fundamental and developmental research, standards of research performance, and independent versus directed research.

*The Conservation Council* under the chairmanship of Charles C. Adams, New York State Museum, Albany will hold a Saturday afternoon session, 30 March, 2:00 P.M.; private dining room 5, Jefferson Hotel. An informal conference has been called by the temporary officers of the Conservation Council to discuss suggestions and plans for the formation of a permanent organization devoted to the integration of active interest in organizations within the general field of conservation.

*The Society for the Study of Speciation* will hold a Saturday morning session, 30 March, 8:30 A.M. in private dining room 2, Jefferson Hotel under the chairmanship of Alfred E. Emerson. The Society for the Study of Speciation is a new group first organized in 1941 for those interested in the dynamics of evolution. In preparation for a fresh start, following an inactive period during the war, this meeting is called to discuss organization and objectives and to elect officers.

## About People

*Dr. Carlyle F. Jacobsen,* formerly professor of psychology and assistant dean of the Washington University School of Medicine, St. Louis, has been appointed dean of the Graduate College at the State University of Iowa, effective 1 April.

*Dr. Roger Adams,* head of the Department of Chemistry in the University of Illinois and member of the *Science* policy committee, has been awarded the Davy Medal of the Royal Society of London. Dr. Adams, who spent the war years in Washington with NDRC, is now in Berlin as special adviser to Lt. Gen. Lucius D. Clay, deputy military governor of the American occupation zone in Germany.

Dr. Adams served the AAAS on the Executive Committee 1940–1945, has been vice-president of Section C, was president of the American Chemical Society in 1935, and is now chairman of its Board of Directors.

*Dr. William C. Biel* has joined the Denison University faculty as associate professor of psychology and director of special projects in industrial research at Newark, Ohio.

*Dr. Richard V. Morrissey* has been appointed assistant professor of biological sciences at Denison University.

*Glenn L. Jepsen,* associate professor, Princeton, has been appointed to the William J. Sinclair professorship of vertebrate paleontology in the Department of Geology at Princeton, effective at the beginning of the academic year 1946–1947. This is the first appointment on this professorship, which was established in honor of William J. Sinclair, who served as professor of vertebrate paleontology at Princeton from 1916 to 1935.

*Benjamin Burack* has been appointed assistant professor of psychology at Roosevelt College, Chicago.

*Dr. Steuart Henderson Britt,* until recently a Lt. Commander, USNR, serving in the Headquarters of the Commander in Chief, U S. Fleet, has become the associate director of research of McCann-Erickson, Inc.

*Dr. Edward Asahel Birge,* president emeritus of the University of Wisconsin, recently celebrated his seventieth year of continuous service. On 5 January 1875 Dr. Birge came to the University of Wisconsin, at the age of 24, as an instructor in natural history. Now 94 years of age, Dr. Birge is considered "the grand old man" of Wisconsin's and America's scientists-scholars-educators. Still in good health, he spends part of each day, even though he technically retired 21 years ago, at work in his office in the biology building on the Wisconsin campus. He learned to operate a typewriter as he approached his ninetieth birthday and still does much of his own typing. At present he is working on a volume on the physical, chemical, and biological conditions of Wisconsin's lake waters, a field in which he has specialized since retiring as president of the University in 1925.

*Dr. Sidney M. Newhall,* formerly technical director of the Fire-Control Research Laboratory at the Foxboro Company, is now in charge of psychological research in the Color Control Department of the Eastman Kodak Company.

*Dean A. M. Schwitalla,* S.J., of St. Louis Medical School, will be the speaker at the Graduation Exercises of the University of Texas Medical Branch, Galveston, on Saturday, 2 March.

*Ian Campbell* has returned to his position as associate professor of petrology and associate chairman of the Division of the Geological Sciences at the California Institute of Technology in Pasadena. During his leave of absence from the California Institute, Dr. Campbell served as a senior training engineer and as chief of the editorial section for the University of California, Division of War Research, at the U. S. Navy Radio and Sound Laboratory in San Diego.

*Morris A. Stoltz,* formerly chief chemist of the Anglo-French Laboratories, consultant to E. Fougera and Company, and chemist of the Loeser Laboratory, is now chief chemist in charge of ampule production at the Leader Laboratory, Brooklyn, New York.

*Lt. Col. Harry E. Carnes, M.C.,* has returned from the armed forces and is now in the Division of Biological Production at Parke, Davis and Company, Detroit, Michigan.

*Lt. Robert L. Burwell, Jr.,* has returned to Northwestern University as assistant professor of chemistry after three years of active duty in the Navy. During most of this period he was attached to the Chemistry Division of the Naval Research Laboratory, Washington, D. C.

*Charles V. Crittenden,* formerly with the U. S. Office of Strategic Services, has been appointed assistant professor of geography at Ohio State University. Prof. Crittenden was attached to the map intelligence office of OSS for three and a half years, with about 18 months service in Switzerland and Italy in the procurement of special maps.

*Marcel Raymond,* botanist, assistant secretary of the Association Canadienne Française pour l'Avancement des Sciences, has arrived in Montreal from Paris, where he was delegated to assist at the first congress of the French Association for the Advancement of Science held since the beginning of the war, in October last.

*Dr. Valy Menkin,* Department of Pathology, Duke University School of Medicine, addressed the Baltimore Medical Society on 1 February 1946 on "Chemical Factors and Their Role in Inflammation."

*Dr. Irwin M. Korr* has been appointed professor of physiology at the Kirksville College of Osteopathy and Surgery.

*Dr. Lawrence C. Curtis,* geneticist on the staff of the Connecticut Agricultural Experiment Station at New Haven since 1930, has joined the faculty of the University of Connecticut, Storrs, to do research and teaching as associate professor of horticulture.

*William R. Bascom* is now an assistant professor in the Department of Anthropology at Northwestern

University. He has just returned from three years with the Foreign Economic Administration as special representative to British West Africa, with headquarters in Accra.

*Dr. Robert M. Moore,* professor of surgery, has recently returned to the Medical Branch of the University of Texas after services in the European theater.

*Dr. M. F. Guyer,* emeritus professor of zoology at the University of Wisconsin, has been made a lecturer in genetics at the University of Texas Medical Branch, Galveston.

*The New Year Honors List,* published in *The Times,* London, 1 January 1946, reveals that Prof. A. V. Hill, Sc.D., F.R.S., a secretary of the Royal Society, was appointed a companion of honor. Other orders were conferred on Mr. W. A. Akers, director of atomic bomb research, Department of Scientific and Industrial Research (knight bachelor); Sir Edward Victor Appleton, F.R.S., secretary, Department of Scientific and Industrial Research (G.B.E.); Clive Forster-Cooper, F.R.S., director, British Museum of Natural History, (knight bachelor); Harold Arthur Thomas Fairbank, consultant adviser in orthopedic surgery, Ministry of Health (knight bachelor); Paul Gordon Fildes, F.R.S., director of chemical bacteriology, Medical Research Council (knight bachelor); Archibald Montague Henry Gray, dermatologist, University College Hospital (knight bachelor); Prof. Ian Morris Heilbron, F.R.S., lately scientific adviser, Ministry of Production (knight bachelor); R. V. Jones, assistant director of intelligence (Science), Air Ministry (C.B.); A. K. Macbeth, Angus Professor of chemistry, University of Adelaide (C.M.G.); Frank Charles Mears, president, Royal Scottish Academy (knight bachelor); Edward James Salisbury, D.Sc., F.R.S., director, Royal Botanic Gardens, Kew (knight bachelor); Herbert Ray Stewart, vice-chairman, Imperial Council of Agricultural Research (knight bachelor); S. Zuckerman, scientific director, R.A.F. Bombing Analysis Unit (C.B.).

## Announcements

*A new interdepartmental acoustics laboratory* has been established at Massachusetts Institute of Technology. The new laboratory is to be operated under the joint direction of the Institute's Departments of Physics and Electrical Engineering and the School of Architecture and Planning. It will collaborate with all departments interested in acoustic problems. Dr. Richard H. Bolt, assistant professor of physics, has been appointed director. He will work with a supervisory committee consisting of Profs. Philip M. Morse, Department of Physics, chairman of the committee; Richard D. Fay, Department of Electrical Engineering; Julius A. Stratton, director of the Research Laboratory of Electronics; and Lawrence B. Anderson, School of Architecture and Planning.

A five-year program of research has been laid out for the acoustics laboratory. One of the most important divisions of this program will deal with architectural acoustics, and the problems to be studied include the physical properties of acoustic materials and structures, as well as functional acoustic design. Special provisions will be made for such investigations by means of experimental full-scale rooms. Studies of special interest include sound absorption, distribution, and transmission in various types of structures.

*A Laboratory of Nuclear Studies* will be established at Cornell University for research in high-energy-particles phenomena, including cosmic rays. The laboratory is to be directed by Dr. Robert F. Bacher, who recently completed his work as head of the Bomb Physics Division at Los Alamos, New Mexico.

In making the announcement, President Day stated that the work of the laboratory would be coordinated with research in several divisions of the university, including chemistry, biological sciences, and engineering, in addition to the Department of Physics. According to Dr. R. C. Gibbs, chairman of the latter department, the new laboratory will become a part of a program of research in his department in which every member of the staff may participate.

*Graduate appointments under the plan for coordination* in the teaching of the sciences at Bryn Mawr College will be made this spring. Three scholarships of $600 each are offered to qualified students who have had undergraduate training in two or more of the natural sciences and who wish to continue study in one of the following fields: biochemistry, biophysics, crystallography, geochemistry, geophysics, or similar interrelated scientific fields.

Three fellowships of the value of $1,000 each are offered to candidates in the same fields who, in addition to undergraduate training, have had at least a year of graduate work in science. Special projects for 1946–1947 will include the study of oxidation-reduction potentials in microorganisms, phase rule studies of geologically important systems, and the investigation of molecular structure of organic compounds by X-ray methods.

The Committee will be glad to consider outlines of problems from applicants for these scholarships or fellowships. For application blanks, address Office of the Dean of the Graduate School, Bryn Mawr College, Bryn Mawr, Pennsylvania. No applications will be received after 15 March.

*One of the most important records of earth motion* the history of seismology was obtained at the test the atomic bomb in Jornada del Muerto (Journey Death), New Mexico, on Monday, 16 July 1945, cording to Dr. L. Don Leet, associate professor of ology at Harvard University, who spoke at the rvard Club of Boston, Wednesday evening, 16 nuary 1946. As far back as 1904, experimental ork led to computations of the wave patterns to be pected from a sharp, vertical impact on the ground. the atomic bomb test, these conditions were dupli- ted experimentally for the first time with enough ergy at the source to permit a thorough study under ntrolled conditions. The resultant observations dif- red widely and significantly from theoretical pre- ctions. The most important feature was the fact at the greatest part of the energy was carried by o hitherto unknown wave types. One of these, the Coupled Wave," was first observed and reported by r. Leet in 1939. Further work on the uses and im- portance of this wave was delayed by the war until it as found to be one of the dominant forms on the tomic bomb record. The other, the "Hydrodynamic Wave," had never before been reported. These two aves were held to be as fundamental to seismology s are atomic structures to nuclear physics.

*A wide program of research embracing the new chemicophysical techniques* has been announced by Dr. Edward R. Weidlein, director, Mellon Institute. This action is in accordance with the organization's aim of strengthening continually its investigational equipment and facilities. Dr. H. R. Klug, formerly in the Department of Chemistry, University of Minnesota, is in charge of this new activity of the Institute. There has been projected a department in chemical physics which will devote about half its time to service to the fellowships and the remainder to fundamental investigations of its own choice. The techniques included are X-ray diffraction, electron diffraction, electron microscopy, chemical microscopy, and the branches of spectroscopy.

*A late-model Zeiss compound binocular research microscope* was stolen from the Massachusetts General Hospital in Boston on 14 January 1946. The instrument has a slanting body, square stage, quadruple nosepiece, and was equipped with paired eyepieces and four objectives when stolen. The stand is No. 271,139; stage, No. 52,238; bitukni, No. 12,135; the Spencer 1b lens, No. 215,790 (brass); low-power Zeiss 8 X lens, No. 138,390 (chrome); high-power Zeiss 40 X lens, No. 153,567 (chrome); oil immersion lens, 90 X, No. 17,959 (brass). The owner, Dr. Richard Bennet Harvey, Massachusetts General Hospital, Boston, reports that the case was not taken.

*The discovery of carbon 14* was announced early in January by Dr. J. Robert Oppenheimer, University of California, according to the *San Francisco Chronicle*. In explaining the difference between carbon 13 (*Science*, 1946, **103**, 82) and carbon 14, Dr. Oppenheimer explained that carbon 13 is a natural carbon isotope. About 1/70 of ordinary carbon is carbon 13. Carbon 14, on the other hand, is not a natural carbon, is radioactive, and is produced in conjunction with the cyclotron. The scientific use of the two carbons, Dr. Oppenheimer said, is approximately the same in principle, however. Carbon 14 was produced at the University by Dr. H. A. Barker, Dr. Martin D. Kamen, and Victoria Haas, a graduate student.

Carbon 14 was produced in a minute quantity by placing 1,000 pounds of ammonium nitrate near the 60-inch Berkeley cyclotron for 18 months. Since carbon 14 is radioactive, its use in biochemical tracer studies is expected.

Dr. Barker and his associates have been able to infuse carbon 14 into organic processes and point out that biochemical tracer studies with a radioactive isotope can be made easier than the more complicated mass spectrographic methods required in the case of carbon 13.

*The Federation of American Scientists*, 1621 K Street, N.W., Washington, D. C., has announced "complete agreement with the principles proclaimed in the President's letter and embodied in the McMahon Bill: (1) Full control over atomic energy developments in this country must be retained by the Federal Government in the interest of the nation as a whole. (2) This control must be exercised through a civilian government agency fully responsible to the President and Congress. (3) The development of science in this country must not be hamstrung by short-sighted and unrealistic policy based on the belief that military security can be achieved by imposition of secrecy in scientific research. (4) Most important of all, national legislation must not obstruct but smooth the path for the future creation of international control and inspection of atomic weapons—the only real chance of security in the age of atomic energy."

The announcement continues: "The McMahon Bill deserves the full support of all enlightened citizens. The control and development of atomic energy for the benefit of this nation and all mankind should not be permitted to become a partisan issue. If a civilian atomic energy authority is not established in the near future and the free flow of ideas and information between scientists in this country is not restored, the development of atomic science in America will suffer a grievous interruption, and chances for the elimination of the terrible danger of atomic warfare by an international settlement will be gravely endangered."

The statement was signed by: W. A. Higinbotham, president, and Melba Phillips, J. H. Rush, J. A. Simpson, Jr., L. N. Ridenour, and L. E. Schiff.

*The American Academy of Arts and Sciences,* at its January meeting, adopted a resolution endorsing United Nations Educational, Scientific and Cultural Organization (UNESCO) as a step toward "the peace of the world." Copies of the resolution were sent to the President, the Secretary of State, members of the American delegation to the UNESCO conference, and to learned bodies all over the world. The resolution follows:

Believing that the peace of the world and the advancement of the arts, the sciences, and education in all countries can be effectively furthered by an active support of the United Nations Educational, Scientific and Cultural Organization, the Council of the American Academy of Arts and Sciences congratulates the Senate and House of Representatives of the Congress of the United States upon the several resolutions adopted by them favoring support of this organization, and urges upon the Congress the desirability of ratifying the charter of the organization on the basis of the signature of our representatives at the London Conference last November.

In order that the widest support may be given to the United Nations Educational, Scientific and Cultural Organization, the Council desires that copies of this resolution shall be sent to all the learned and scientific bodies throughout the world with which it has communication, to the public press, to the President of the United States, the Secretary of State, the Speaker of the House, the President of the Senate, and to the Assistant Secretaries of State.

*The U. S. Naval Academy is to hold examinations* for positions in the Civilian Faculty on 19 and 20 April. The following positions are open: mechanical engineering, 2 assistant professors, 3 associate professors; physics, 2 instructors; electrical engineering, 1 instructor (power), 2 instructors (radio and electronic); mathematics, 13 instructors. Starting salary for instructors is $3,640, for assistant professors $3,860, and for associate professors $4,300. Application forms and notice of requirements may be obtained from the Superintendent, U. S. Naval Academy, Annapolis, Maryland. Application must be submitted prior to 15 March 1946.

*Under a new plan the Navy will finance* special research programs in universities. Essentially, the work will be done under a contract with the institution, and the colleges will be permitted to publish the results of the work providing no reference is made to possible or probable military application. Rear Admiral H. G. Bowen, chief of the Office of Research and Inventions, reported that the following institutions either already have completed contracts or are in the process of doing so: California Institute Technology, Carnegie Institute of Technology, Colu bia, Cornell, Brooklyn Polytechnic Institute, Harva Princeton, Johns Hopkins, Massachusetts Institute Technology, University of Michigan, University Pennsylvania, University of Texas, Syracuse, St ford, University of California, University of Chica University of Illinois, Indiana University, Purd Pittsburgh, Southern California, Tufts, and Yale.

*Ohio State University has established* a gradua center for instruction and research at the Air Te nical Service Command, Wright Field, Dayton, whe graduate-level courses are being offered under t auspices of the Graduate School. The plan now i volves more than 100 graduate students who are e rolled in the current winter quarter in mathemati electrical engineering, and physics classes. Futu development of the graduate center to include class in aeronautical, communication, and power enginee ing, electronics, chemistry, management, and relate technical subjects is planned, according to Dr. Alphe W. Smith, dean of the Graduate School. "The int gration of research and graduate teaching at the u versity with that of the Air Technical Service Co mand is of importance both to the University and t Air Technical Service Command. Such cooperatio between the ATSC and campus scientists brings to t University a unique opportunity to be of service to t nation," Dean Smith said.

*Over one hundred scientists* affiliated with John Hopkins University, Johns Hopkins University Medi cal School, Johns Hopkins University School of Hy giene and Public Health, Carnegie Institute, Gouche College, University of Maryland Medical School, an the Maryland State Health Department have ad dressed a letter to President Truman, Senator Tydings and others, endorsing the joint statement of Mr Truman, Mr. Atlee, and Mr. King, "that a specia commission of the United Nations Organization b created to set up enforceable safeguards against th use of atomic energy for destructive purposes, and that specialized information regarding the practica application of atomic energy be made freely available as soon as these safeguards are established."

The letter continues: "It is our conviction that th problems created by the atomic bomb urgently demand the promptest attention, and that it is the most solemn duty of every member of the Congress to insist that these problems be solved without undue delay. To this end, we hope that the governments of Great Britain, the Soviet Union, and the United States will be able to establish a temporary working agreement regarding the international control of atomic energy, as a basis for action on the matter by the United

ations Organization. Should such an agreement be rmulated by the representatives of these powers, e urge its careful scrutiny by the Congress, and if itable, its prompt ratification."

*Dr. Lise Meitner will deliver a course of lectures* n nuclear physics at The Catholic University of merica during the second semester, 1945–46. The ctures have been scheduled on Tuesdays and Thurs-ys, 5:10–6. A seminar on nuclear physics will held on Fridays, 12–1. Scientists not wishing aca-emic credit may attend as guests of the University ithout formalities.

*In forty years, The New York Times* points out edi-orially, "more than 20,000 voluntary health agencies ave sprung up to deal with virtually every disease nd health problem. It is a credit to philanthropy hat it contributes annually not less than $100,000,000 o these agencies. There is no question that the work one is important and indispensable. But the Gunn-Platt report, which was made possible by a grant from he Rockefeller Foundation, raises questions. Would ne large, well-supported organization be better than undreds of local voluntary organizations? Are these any organizations efficiently directed? Are philan-hropists getting their money's worth? The Gunn-Platt study of 569 voluntary and 143 official agencies eveals much that is good and much that calls for eform.

"There seems to be overspecialization in such fields s child welfare, tuberculosis, mental hygiene, infan-ile paralysis, to mention but a few. Too often four or five independent societies appeal for individual sup-port instead of pooling their resources. There is a reluctance to keep pace with social change, a tendency to regard work in a special field as a vested interest, a lack of relationship between the size and importance of a health task and the money and services available for its performance. One energetic organization, for example, has in eight years raised $16,500,000 to cope with a disease which even in epidemic years accounts for less than 2,000 deaths. But heart diseases, to which 3,700,000 succumb annually, receives only three cents a case.

"Now that we have the Gunn-Platt report, the work of coordination must begin. To this end the Rocke-feller Foundation has made a grant of $78,500, which will enable the National Health Council, a clearing house, to assume dynamic leadership in a movement which is bound to have its effect in improving the health of the country. There are to be joint planning, joint activities and joint services for national agen-cies, a strengthening of established health councils and an active field service to give practical counsel. The work to be undertaken by the National Health Council deserves support."

*Wayne University College of Medicine* invites applications for the Alexander Blain Hospital Fellowship in Anatomy for the year 1 July 1946 to 30 June 1947. This recently established fellowship is for research workers possessing either the Ph.D. or M.D. degrees and who are desirous of further experience in the broad fields of anatomy. Work is encouraged in gross anatomy, comparative anatomy, embryology, neuroanatomy, histology, and cytochemistry. The fellowship carries an annual stipend of $3,500, and the holder is assured of technical aid and funds for special equipment and supplies. Applications for the fellowship should be addressed to: Dean of the College of Medicine, Wayne University, 1512 St. Antoine Street, Detroit 26, Michigan.

*The Marcelle Fleischmann Foundation* has made a grant of $20,000 a year for a 10-year period to the Department of Public Health and Preventive Medicine of Cornell University Medical College for the study of tropical disease. The specified purpose of the gift is to promote the study of immunologic and allergic manifestations of exotic disease, and to provide for a better understanding of their prevention and treatment in relation to other allergic diseases. The investigations at Cornell will be under the direction of Dr. Morton C. Kahn.

*Kirksville College of Osteopathy and Surgery* has announced a research grant of $5,000 by the American Osteopathic Association.

*The National Registry of Rare Chemicals,* Armour Research Foundation, 35 West 33rd Street, Chicago 16, Illinois, lists their need for the following chemicals: acrylic anhydride; acrylyl chloride; sodium phosphide; meta calcium phosphate, vitreous (25 lbs.); α-meta calcium phosphate (25 lbs.); cytochrome C; d- and l-gulose; d- and l-idose; l-ribose; l-lyxose; erbium (1 lb. or more); nitrogen trifluoride; sulfur hexafluoride; boron phosphate; pyocyanin, benzanthrone; hirudin; strychnidine; eleostearic acid; and pantoyl taurine. Please communicate regarding these directly with the Registry at the address given above.

## Meetings

*The 1946 spring meeting of the Crystallographic Society* will be held at Smith College, Northampton, Massachusetts, on Thursday, Friday, and Saturday, 21–23 March. The sessions will be in Lilly Hall, Department of Physics. Those desiring accommodations on the Campus should write to the chairman of the local committee, Dr. Dorothy Wrinch, 81 Woodside, Amherst, Massachusetts. Additional accommo-

dations are available at Northampton Hotel, Northampton. Further literature on arrangements may be had by writing to the Secretary of the Society, Dr. William Parrish, Box 39, Irvington, New York. The program follows:

*Thursday,* 3:00 P. M.—"Crystallography, a Common Ground in Many Sciences": I. Fankuchen, Brooklyn Polytechnic Institute; "The Lattice in Crystallography": J. D. H. Donnay, Johns Hopkins University; Late contributions; Tea, Department of Physics, Smith College. *Thursday,* 7:30 P. M.—"The Modifications of Silicon Carbide": N. W. Thibault, Norton Company; "Plastic Deformation and Recrystallization of Nonmetal Crystals": Edward Washken, Massachusetts Institute of Technology; Informal Hour, home of Prof. Benjamin M. Shaub, Department of Geology, Smith College. *Friday,* 9:30 A. M.—"Crystallographic Principles and Biological Problems": Dorothy Wrinch, Smith College; "Types of Order in Protein Fibrils": R. S. Bear, Massachusetts Institute of Technology; Late contributions. *Friday,* 2:30 P. M.—Business Meeting Crystallographic Society; Tea, Department of Physics, Smith College. *Friday,* 7:30 P. M.—"Optical Activity in Crystals; Crystallography of l-Cystine": C. D. West, Polaroid Corporation; "Experimental Study of the Change in Habit of Sodium Nitrate Crystals Grown From Water Solution": Howard T. Evans, Jr., Massachusetts Institute of Technology; "Variations in Crystal Habit of Pyrite in the Collins Hill Pegmatite Near Middletown, Connecticut": Benjamin M. Shaub, Smith College; "Twinning in Leadhillite": Samuel G. Gordon, The Academy of Natural Sciences of Philadelphia; Informal Hour, home of Prof. Gladys Anslow, chairman of the Department of Physics, Smith College. *Saturday,* 9:30 A. M.—"The Use of Sand in Making Fourier Projections of Crystal Structures": Dan McLachlan, Jr., and E. F. Champaygne, American Cyanamid Company; "Graphical Summation of Fourier Series in Crystal Structure Analysis": Joseph Lukesh, Massachusetts Institute of Technology; "Crystal Pattern Synthesis by an Approximate Summation of Fourier Series": Joseph Lukesh, Massachusetts Institute of Technology; Late contributions.

*The Sixth Conference of the Institute of Food Technologists* will be held on 18, 19, and 20 March at the Statler Hotel, Buffalo, New York. A total of 37 papers on the broad scope of food technology have been scheduled for the six technical sessions. In addition, an afternoon session consisting of eight papers is planned for those primarily interested in milk processing problems. Another afternoon session with a program of six papers is being devoted to frozen foods.

## Elections

*The New Hampshire Academy of Science* held its twenty-fifth annual meeting at Hanover on 23 and 24 November 1945. The following officers were elected for 1945–1946: William W. Bowen, Dartmouth College, president; Donald Chapman, University of New Hampshire, vice-president; A. R. Hodgdon, University of New Hampshire, secretary-treasurer; and Roy P. Forster, Dartmouth College, member of the Council for four years.

*The District of Columbia Chapter of the Society of Sigma Xi* inducted three new members at the annual meeting held in the Cosmos Club on 29 January. Those honored and the subjects of their addresses were: Dr. Myron S. Anderson, senior chemist, U. S. Department of Agriculture, Beltsville, Maryland—"Nineteen Centuries of Soil Fertility"; Capt. Ernest W. Brown, USN (MC), Navy Department—"The Submarine: Certain Problems of Atmosphere"; Dr. John B. Reeside, Jr., chief, Paleontology and Stratigraphy, U. S. Geological Survey—"Why Study Fossils?"

*The Shell Development Research Club,* Emeryville, California, affiliated with the Society of the Sigma Xi, has announced its Council officers for 1946. These include: Harold T. Byck, chairman; William E. Vaughan, past chairman; Fred H. Stross, chairman-elect; Kenneth E. Marple, secretary; and Daniel B. Luten, treasurer.

## Recent Deaths

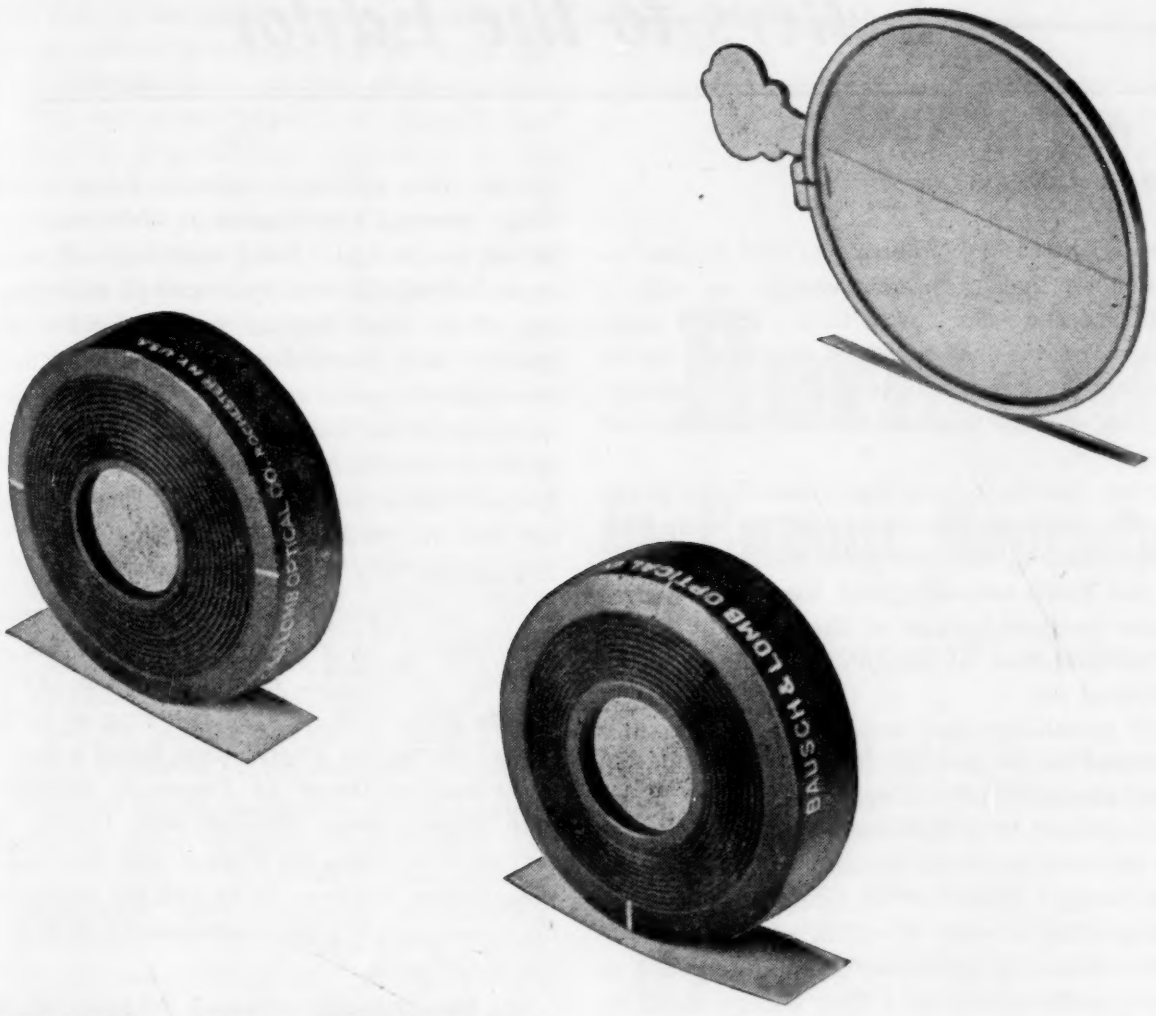
*Dr. Otto Neurath,* 63, died in Oxford, England, on 22 December. Dr. Neurath was the inventor of isotypes, the small symbols used to make statistical presentations less abstract. In the United States these symbols are more generally known a "pictographs."

*Dr. Edward W. Koch,* 64, dean of the University of Buffalo Medical School, died on 9 February.

*Dr. Walter P. White,* 78, retired Carnegie Institute physicist, died on 7 February.

*Prof. Joseph M. Scott,* 56, for 25 years professor of biology at Mount Union College, Alliance, Ohio, died on 1 February.

*Dr. C. V. Taylor,* 61, dean of the School of Biological Sciences at Stanford University, died in Palo Alto, California, on 22 February.

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# STEREO-POLARIZER EQUIPMENT

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# Letters to the Editor

## Nuclear Energy and the Polar Icecap

Probably no scientific development has ever aroused as much discussion as that of atomic energy, or nuclear energy, which is a more descriptive title. This is properly so. It is inevitable that informed discussion should be accompanied by preposterous ideas, such as automobiles running on engines the size of one's fist supplied with nuclear power.

The statements that have been made recently by prominent people that with the advent of nuclear energy we are now in a position to melt the polar icecaps have evidently been put forth seriously, and have even caused concern in some quarters because of the threat of a general raising of the level of the oceans, the effect on weather conditions, etc.

On the bare possibility that some readers of *Science* have not bothered to go through the simple calculation that shows the absurdity of this proposal at the present stage of developments, it is presented herewith.

The icecap has been estimated to cover 5,000,000 square miles and to average 1,800 feet in thickness. To melt it from a temperature of $-40°$ F. would require $2.5 \times 10^{23}$ B.T.U. of heat, which is equivalent to $3 \times 10^{26}$ joules or $2 \times 10^{45}$ electron volts of energy. This energy could be supplied as nuclear energy in two ways: by dropping bombs or by setting up so-called piles such as are used in the production of plutonium.

Each atom of U-235 releases about $2 \times 10^{8}$ electron volts of energy. Operating at 100 per cent efficiency it would, therefore, require $10^{37}$ atoms or something over four billion tons of U-235 to do the job. At present costs of something over $10,000 per pound no comment is needed regarding the feasibility of this approach. The idea of using uranium piles is no more feasible. Surely a pile that dissipates 1,000,000 kilowatts would be considered a large one. The power output would be about equivalent to that of the Grand Coulee dam. With 10,000 such piles one could melt the icecap in about 1,000,000 years.

The foregoing remarks are not intended to detract in the slightest from the enormous possibilities that have been opened up by the introduction of nuclear energy. Those possibilities are surely great enough to tax the imagination of anyone to the limit and offer enough perplexing problems without introducing such ridiculous propositions as the one dealt with here.

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## Transmission of Papaya Bunchy Top by a Leaf Hopper of the Genus *Empoasca*

A serious disease of papaya (*Carica papaya* L.), widely known under the name of "bunchy top," has been reported from different regions of the world where the plant grows. The disease is characterized during its initial stages by a faint mottling and chlorosis of its upper leaves, followed by a marked reduction and yellowing of the leaf lamina and a decided shortening of petioles and internodes, ending finally in a complete cessation of apical growth and bunchiness of the top which gives the disease its peculiar name. Another conspicuous symptom of the disease is the presence of hydrotic-like streaks, sometimes called "oil spots," along the stem and petioles.

Although long suspected to be a virus disease, nobody, as far as we know, has been able to transmit it either mechanically, by grafting, or through the aid of insect vectors. In 1937 J. H. Jensen (*Rep. Agric. Exp. Sta. Puerto Rico*, 1938, p. 125), working at the Federal Station at Mayaguez, Puerto Rico, found a leaf hopper, later described by Oman as *Empoasca papayae*, associated with papaya trees affected with bunchy top. His attempts to transmit the disease with this leaf hopper were inconclusive, however, as he had the misfortune of losing his experimental plants accidentally shortly before leaving the Station.

We have recently obtained evidence of the successful transmission of bunchy top with a leaf hopper of the genus *Empoasca* which, based on an examination of the male genitalia, we presume to be identical with the one used by Jensen. Seventy-one out of 90 healthy trees exposed to leaf hoppers collected on diseased plants began to show symptoms of bunchy top in about a month and a half. Most of the experiments were performed in insect-proof cages, but in some cases the insects were released inside cellophane casings inserted on the upper stem of the test plant after trimming the leaves. Unexposed controls (5 for every 10 plants exposed) remained healthy.

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## Geopathology, a Branch of Biometeorology

In his recent article on "Tropical diseases and geopathology" (*Science*, 1945, **102**, 656) Dieuaide stresses the fundamental importance of studying "the peculiarities of disease in relation to topography, climate and the distribution of pathogenic and disease-transmitting organisms," suggesting that "geopathology" be used to designate such a field of investigation. With this point I agree, but the author is in error when he states that (1) geopathology is in its infancy, (2) there are no geopathologic treatises even moderately comprehensive, and (3) our knowledge is fragmentary.

Although the fact is not widely known, geopathology is a branch of an already established science called biometeorology. Hippocrates knew of these problems when he wrote his *Airs, waters and places,* and Hirsch's and Drake's treatises on geopathology, published in the 1850's, are classics of medical literature. For many years, however, interest in these problems has been lacking, but along with the recent growth of interest in the problem of constitution, investigations of the influence of the environment on man have appeared in increasing numbers. In particular, workers both in this country and in Europe have been studying the influences of weather, climate, and altitude on plants and animals. This study has been designated biometeorology, and in 1939 a section devoted to the literature of this field was founded in *Biological Abstracts* under the section on Ecology. Some of the divisions of biometeorology are medical climatology, meteoropathology, geopathology, and climatotherapy. At the present time the Committee on Climatology of the American Geophysical Union is attempting a classification of the branches of biometeorology so that the existing and forthcoming literature will be readily available to the interested workers.

Although our knowledge is incomplete, it is certainly not fragmentary; for there is already available a vast literature on biometeorology. In recent years a number of excellent monographs have appeared, summarizing some of that knowledge. W. F. Petersen's *The patient and the weather* (4 vols., 1934–1938) and M. Piery's *Traité de climatologie: biologique et médicale* (3 vols., 1934) are among the most extensive. B. de Rudder's *Grundriss einer Meteorobiologie des Menschen* (1938) outlines many of the fundamental principles of the science. C. A. Mills' *Medical climatology* (1939) is an analysis of the seasonal and geographical variation of disease. A. G. Price has admirably analyzed the problem of the *White settlers in the tropics* (1939), and D. H. K. Lee (*Univ. Queensland Pap.,* 1940, **1**, 1–86) has summarized the literature on the physiology of acclimatization.

I do, however, agree with Dieuaide that there is a great need for a systematic investigation of these problems, for a correlation of available literature to serve to focus attention on the problems requiring further study, and for collaboration among the interested investigators so that the research may be carefully planned and efficiently executed to reveal the facts and make the acquired knowledge applicable.

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### Retention of High School Science

When I read the recent comment of Charles A. Gramet concerning secondary school science courses (*Science,* 1946, 103, 149), I felt that a reply was necessary.

A few years ago I gave a college pretest in biology, at the time requesting that those who had studied the subject in high school indicate that fact. The results astonished me. Of some 50 students who had studied secondary school biology, only 10 ranked higher than

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those who had none, and in no case was the increase in percentage more than 5 points.

Within the past 10 years I have taught in several high schools in widely separated places; I have also inspected numerous others. It has been my experience that the science teaching in most of these was very poor. Inadequate equipment, inadequately trained teachers, and, especially, administrative interference with classroom work accounted for this.

By interference is not meant meddlesome supervision, but the insistence that extracurricular nonsense be injected into study and class periods. In one school, for example, my chemistry class was interrupted daily by a loud-speaker broadcast of school gossip which (the school being small) was already familiar to the students, and this was by no means the only case.

College teachers have constantly to erase misconceptions acquired in the lower schools: One certainly becomes tired of hearing about "pure and impure blood," "nerves carrying messages," that "spores are seeds," and that "plants breath out oxygen." And although biology seems to suffer especially, similar misconceptions are numerous with respect to the other sciences.

One can agree most heartily with Mr. Gramet that we need to teach more science in the lower schools. But also needed are teachers meticulously careful not to instill wrong concepts. Poor results will continue as long as school boards insist that a music teacher give courses in biology and that the football coach teach physics. They will continue as long as textbooks, in order to simplify explanations, give wrong explanations. Especially will they continue as long as the "pep meeting" is so important that the entire business of the school is interrupted as a consequence.

The wonder is that children in high school learn anything at all.

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# Catalogue Corner

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